SEASON OF ARRIVAL AND GEOGRAPHIC REGION OF ORIGIN AFFECT FEEDLOT PERFORMANCE, HEALTH, AND CARCASS TRAITS OF ANGUS STEERS

by

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ABSTRACT

Angus steers (n = 17,919) fed at a single feedlot in southwestern Kansas between 1997 and 2007 were used to evaluate the effects of various demographic and phenotypic characteristics (season of arrival, geographic origin, health status, rate of gain, quality grade, and yield grade) on feedlot health, performance, and carcass traits. Cattle were not commingled and were predominantly preconditioned and backgrounded prior to shipment to the feedlot. Season of arrival was categorized as winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), or fall (September, October, and November). Regions were: SC = Texas, Oklahoma, and New Mexico; C = Colorado and Kansas; NC = Montana, Nebraska, and Wyoming; and SE = Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia. Steers that originated in SC had the poorest ADG ($P < 0.01$) and those originating in C had the greatest ADG, HCW, and quality grade ($P < 0.01$). Steers that arrived during fall had the lowest ADG and those arriving during the summer had the greatest morbidity ($P < 0.01$). Morbidity decreased and performance increased with increasing initial BW; quality grade was only minimally related to arrival BW in steers which were not treated for disease. After accounting for yield grade differences, the association between morbidity and carcass quality and between quality grade and heavier final BW and HCW were diminished, although ungraded cattle had lower ADG, final BW, and HCW ($P < 0.01$). Increasing yield grade from 1 and 2 to yield grade 3 increased percentage Choice by 12.1 points ($P < 0.01$); there was no additional gain in quality grade moving to yield grade 4 and 5. More rapidly gaining steers were heavier and fatter at marketing; this translated to greater quality grade in all but steers with initial BW > 375 kg. Performance was very similar among cattle which graded Prime, Choice, and Select, suggesting that producers do not need to choose between performance and quality grade; instead, much of the difference in quality grade can be explained by differences in yield grade.

Key words: carcass, feedlot, morbidity, quality grade, season

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CHAPTER 1 - A Review of Literature

Growth and Development of Feedlot Cattle

In order to maximize the genetic potential of cattle it is important to understand the development and growth process. However, it is necessary to note the difference between development and growth. In mammals, chronological, physiological, social, mental, and emotional development proceed at different rates (Owens et al., 1993). Growth on the other hand is defined as an increase in tissue mass, or the accretion of protein, fat and bone (Owens et al., 1993; Owens et al., 1995). Growth includes not only cell multiplication (hyperplasia) early in life but also cell enlargement (hypertrophy) later in life (Owens et al., 1993). Even though muscle mass is of primary interest in meat production, growth also includes the deposition of fat (Owens et al., 1993).

Mature Body Size and Nutrient Restriction

Mature body size is generally considered the point at which muscle mass reaches a maximum (Owens et al., 1993). When cattle reach their mature body size, body fat content is approximately 36% of empty body weight regardless of sex and background (Owens et al., 1995). For finishing steers and bulls gaining more than 1.3 kg daily, rate of fat accretion appears to plateau at approximately 550 g daily (Owens et al., 1995). In contrast, protein accretion rate depends on age and mature body size, and increases as rate of empty body weight gain increases (Owens et al., 1995). The protein:fat ratio of the carcass can be increased by increasing mature size (Owens et al., 1995). In a serial study by Bruns et al. (2004) the percentage of whole carcass fat increased linearly, whereas whole carcass protein and whole carcass moisture decreased linearly with increasing harvest weights. A limiting factor to the growth of a tissue is the mature weight of the animal (Bruns et al., 2004). As an animal grows, reaching mature body size, the rate at which tissues develop slows, but the proportionality of tissue growth changes (Bruns et al., 2004). Although the maximum body size is genetically determined, it can be altered by nutritional and hormonal factors or harvesting finished cattle at an earlier stage of maturity (Ownes et al., 1993).

Whether mature size of cattle can be altered through nutritional restriction remains debated (Owens et al., 1993). The size of an animal when it reaches its mature size has been reported to be decreased, unchanged, or increased depending on the severity of the restriction and the nutrient involved. Very severe nutrient restriction, particularly protein, has been reported to reduce mature body size and increase fat content of the carcass (Berg and Butterfield, 1976; Pond et al., 1990; Widdowson and Lister, 1991). In contrast, a moderate degree of restricted feeding during growth did not alter mature weight of finished steers (Winchester and Howe, 1955; Winchester and Ellis, 1956). Other researchers have reported restricting energy intake during the late prepubertal or early postpubertal period markedly reduces fat content of finished steers at a specific weight (Lake et al., 1974; Lewis et al., 1990b). Thus, producers might be able to alter the mature weight of animals by altering the length of restriction and/or age of the animal at which nutrient restriction occurs (Owens et al., 1993).

Nutrition Effects on Body Composition

Tissues grow and develop chronologically in specific "growth waves" (Owens et al., 1993). Certain tissues grow and mature before others; growth starts with neural tissue and proceeds to bone, muscle tissue, and finally adipose tissue (Owens et al., 1993). Within each of these tissues, development can be early, medium, or late depending on its location in the body

(Owens et al., 1993). Therefore, supply of dietary nutrients must be coordinated with this progression to maintain optimum growth rates (Owens et al., 1993).

Cattle feeders commonly attempt to alter mature size during a growing period between weaning and entry into the feedlot. A growing period or backgrounding involves feeding for moderate growth, allowing for maturation of muscle and bone while restricting fat deposition (Block et al., 2001). Greathouse (1985) reported when earlier maturing cattle (small framed cattle and heifers) were fed high energy diets as calves, they exhibited enhanced fattening and reduced harvest weight at a specified fat thickness. Because light weight carcasses receive discounts at harvest, a growing period is utilized after weaning with a goal of growing frame and muscle. Consequently, this delays fat deposition so that carcasses of animals with enough intramuscular fat to grade Choice will have greater and thereby more acceptable carcass weights (Owens et al., 1993). On the other hand, large-framed cattle do not require this growing period. Block et al. (2001) reported large-framed steers had greater hot carcass weights when compared to medium-framed steers in short- and long-term backgrounding programs.

Mature size may be reduced by an oversupply of energy during the middle phase of growth. Possibly some signal from lipid mass decreases the rate of protein deposition (Owens et al., 1993). In contrast, when an animal's mature size is reduced because of severe energy or protein restriction during the early growth phase, it is due to some permanent reduction in either nutrient supply (damage to the digestive tract) or in satellite cell or muscle fiber number (Owens et al., 1993). An inadequate supply of substrate (amino acids, ATP) can limit the rate of protein synthesis during growth (Bergen, 1974). Thus, nutrient supply regulates the amount of protein synthesis "machinery" (RNA) (Owens et al., 1993). Total protein deposition can be limited by nutrient supply, but with high intakes of a well balanced diet, the maximum rate of protein deposition seems to be limited by concentrations of growth-stimulating hormones (Owens et al., 1993).

Hormone Effects on Body Composition

Various hormones and growth factors alter growth rate or body composition. Endogenous (i.e., insulin, somatotropin, IGF-I and IGF-II) and exogenous hormones promote translation, transcription, and amino acid uptake (Owens et al., 1993). Within these hormones come estrogenic (i.e. estradiol, progesterone, zeranol) and androgenic (i.e. trenbolone acetate) compounds used in anabolic implants which are commonly used in the feedlot (Schmidt and Olson, 2007). There are three general types of anabolic implants: estrogenic, androgenic, and combination. Many times combination implants are used that contain both estrogenic and androgenic hormones that will produce a greater response. Estrogenic implants exert their influence primarily by way of increased production and release of hepatic somatotropin and insulin-like growth factor 1 (Reinhardt, 2007). These secondary hormones stimulate muscle protein accretion (Reinhardt, 2007). Androgenic implants act primarily by way of direct action on muscle tissue, stimulating protein synthesis and reducing protein catabolism (Reinhardt, 2007). Anabolic implants shift the composition of gain in cattle by increasing protein deposition and decreasing fat at a particular weight (NRC, 1984, 2000).

Implants reduce the physiological age of the animal, thus they are in a less mature and leaner stage of growth (Reinhardt, 2007). Even though implanted cattle gain faster than nonimplanted cattle, they are unable to accumulate fat at a rate proportional to their increased growth (Reinhardt, 2007). Implanted animals reach the same body composition at a heavier weight compared to nonimplanted cattle (Hutcheson et al., 1997; Perry et al., 1991). Guiroy et al. (2002) reported finished BW is increased from 14 to 42 kg in steers and 30 to 39 kg in heifers, in order to reach a common body composition at harvest compared to cattle that do not receive an implant, depending on the implant strategy used. Guiroy et al. (2002) indicated that anabolic implant response is due to a combination of a reduced proportion of the DMI required for maintenance, reduced energy content of gain, and efficiency of use of absorbed energy.

Another class of chemicals that can alter composition and tissue growth are the β-adrenergic agonists (Owens et al., 1993). When activated, β-receptors in adipose tissue stimulate lipolysis, and in muscle tissue they increase protein synthesis (Mersmann, 1998) and decrease protein degradation (Muir, 1988; Morgan et al., 1989). Fat deposition is decreased and net protein deposition is increased (Owens et al., 1993; Mersmann, 1998).

Compensatory Growth Effects on Body Composition and Performance

Bohman (1955) coined the term compensatory growth which describes the accelerated and more efficient growth that commonly follows a period of growth restriction. This growth rebound represents rapid hypertrophy of muscle tissue (Owens et al., 1993). The magnitude of compensatory growth is greater when it follows energy restriction rather than protein restriction (Drouillard et al., 1991a, b). The magnitude of compensatory growth depends on a number of factors. These include age when restriction begins; the severity, duration, and nature of the restriction; the realimentation diet and time; and the breed type (Moran and Holmes, 1978; Hogg, 1991).

Results from compensatory gain experiments are in conflict in regard to animal performance, feed intake, and carcass composition (Sainz et al., 1995). The degree of restriction and altered maintenance requirements play a major role in determining the magnitude of the compensatory growth response (Abdalla., 1988; Sainz et al., 1995). Sainz et al. (1995) reported growth restriction during the growing phase resulted in compensatory gains in the finishing period. Higher dry matter intakes following growth restriction were accompanied by increased rates of live weight and empty body weight gain (1.92 vs. 1.09 kg/d) and improved feed efficiency when cattle were fed high concentrate diets during the finishing phase (Sainz et al., 1995). Abdalla et al. (1988) observed 14 to 30% higher growth rates for steers fed a low protein diet followed by a high energy diet when compared to cattle that were not restricted. Cattle that were fed a restricted diet required 12 to 117 more days to reach a similar percentage of body fat (Abdalla et al., 1988).

Sainz et al. (1995) reported carcass fat content was unaffected, but fat distribution was altered so that growth-restricted/re-fed steers had less subcutaneous and more internal fat. Marbling scores were similar among cattle that were allowed *ad libitum* access to feed and restricted animals during the growing phase, if allowed *ad libitum* access to feed during the finishing phase (Sainz et al., 1995). However, marbling scores were lower for cattle restricted during the finishing phase (Sainz et al., 1995). Dockerty et al. (1973) concluded beef cattle subjected to a period of temporary energy restriction were equal in quality grade to continuously fed cattle, whether fed a high or low energy diet. Winchester and Howe (1955) found that a period of undernutrition between the age of 6 months and 1 year did not adversely affect meat quality or the proportion of lean in beef carcasses at final weight. In contrast, Carroll et al. (1963) reported that continuously fed steers had a greater amount of marbling than those whose energy intake was restricted. Dockerty et al. (1973) reported that while the skeleton elongated and matured normally, muscle deposition increased at a reduced rate, and in combination with the reduction in carcass fat, conformation was lowered for cattle that experienced an energy restriction period.

In addition to genetics, hormonal factors, and nutrition there may be additional factors that influence growth rate directly or indirectly. These factors may include: environmental temperature, day length, breed type, parasites, disease, competition, and (or) exercise (Owens et al., 1993). However, it is unknown how these factors might affect growth and composition. Some may act through controlling feed intake of animals and the supply of nutrients above maintenance; others may alter blood hormone concentrations, blow flow, and nutrient supply to specific body organs or locations (Owens et al., 1993).

Castration Effects on Feedlot Performance and Carcass Traits

Several reports have shown that intact beef males have advantages in feedlot performance and percentage of retail product when compared to steers. However, carcasses from intact males have repeatedly been inferior in quality grade (Arthaud et al., 1969; Landon et al., 1978; Gregory et al., 1983; Worrell et al., 1987). Gregory and Ford (1983) suggest that the majority of the advantage in rate and efficiency of gain of intact males may be expressed by 1 year of age. Therefore, delaying castration may be an approach for increasing performance in the feedlot without reducing the carcass characteristics of harvest animals (Ford and Gregory, 1983; Gregory et al., 1983).

A number of studies have evaluated the effects of age and weight at castration on feedlot performance and carcass characteristics. Champagne et al. (1969) reported bulls gained more rapidly and efficiently than castrated cattle while no differences among the castrated groups in feedlot performance were seen. In a study performed by Klosterman et al. (1954), an early vs. late age of castration of beef males had no effect on feedlot performance. Ford and Gregory (1983) reported intact males gained 24% faster and consumed 22% less feed/unit of gain than castrated males. Worrell et al. (1987) reported intact males gained faster (1.46 vs. 1.26 kg/d, respectively) and were more efficient (4.92 vs. 6.25 feed:gain, respectively). Similar findings were reported by Field et al. (1964), Hedrick (1968), and Arthaud et al. (1977).

The negative aspect of delaying castration or harvesting intact males is the detrimental effects to meat quality. Carcasses from intact males generally have less marbling, a coarser textured, darker colored lean, and less tender meat (Arthaud et al., 1977). Champagne et al (1969) reported castrated cattle produced carcasses with higher quality grades than bulls, as a result of superior marbling scores and more youthful carcass characteristics. However, with each increase in castration age, an increasing trend toward a greater yield of trimmed, boneless retail cuts was also seen (Champagne et al., 1969). Champagne et al. (1969) also observed castrating at 2 and 7 months resulted in fatter carcass that had higher marbling scores than castrating at 9 months, while age at castration did not affect loin eye area, carcass conformation, or overall maturity. Landon et al. (1978) reported that castrating at birth rather than at weaning (205 d) produced steers that had greater dressing percentages, carcasses with greater marbling scores, and, as a result, greater quality grades. Gregory and Ford (1983) reported castrated males had greater fat thickness at the 12th rib (0.75 vs. 0.43 cm, respectively), greater marbling scores (9.3 vs. 6.6, respectively) and lower cutability (63.5 vs. 67.1%, respectively) and retail product (77.8 vs. 82.2%, respectively) percentages than intact males. Worrell et al. (1987) reported castration at 70 or 230 kg resulted in greater marbling scores than castrating at heavier weights or not castrating. Intact males had the lowest marbling scores, although not substantially lower than castrating at 320 or 410 kg (Worrell et al., 1987). Ford and Gregory (1983) concluded that late castration (13 months of age) reduced carcass weight, cutability, and retail product percentage. Dressing percentage, marbling score, final maturity, lean color and lean texture were not affected by late castration (Worrell et al., 1987). Therefore, the studies suggest the younger an animal is at the time of castration the more marbling there will be deposited in the ribeye muscle.

Backgrounding Effects on Feedlot Performance and Carcass Traits

Following weaning cattle may enter a backgrounding/yearling program, or enter the feedlot as calf-feds, or a program that is in between calf-feds and yearlings. Backgrounding is the production phase between weaning and placement into a feedlot for finishing (Thomson and White, 2006). Backgrounding involves feeding to attain a moderate growth rate, allowing for maturation of muscle and bone while restricting fat deposition (Block et al., 2001). Many producers will implement backgrounding systems to utilize available forages; however, animals may also be confined to a dry lot and fed grain-based rations. In yearling programs cattle are nutritionally restricted to varying degrees and for various times (Klopfenstein et al., 1999). They make compensatory gain on grass and then make additional compensatory gain when they enter the feedlot at 12-18 months of age (Klopfenstein et al., 1999). Previous nutrition that restricts cattle growth and limits body fat deposition can positively affect cattle performance in the feedlot through increased growth (Hersom et al., 2004).

About 30% of calves produced in the United States enter the feedlot as calf-feds (Klopfenstein et al., 2000). Calf-feds enter the feedlot directly from weaning or 30-40 days later weighing 227-273 kg on average (Klopfenstein et al., 2000). Cattle placed directly on high concentrate diets after weaning have greater gains, less DMI, are more efficient and cost effective while being harvested at a younger age (Myers et al., 1999). The perception in the feedlot industry has been that calf-feds have lower quality grade compared to backgrounded cattle (Berger, 2004). However, Myers et al. (1999a,b,c) reported steers fed high concentrate diets from weaning to harvest had a greater percentage of carcasses that graded USDA average

Choice or higher than steers that grazed on pasture prior to entering the feedlot. Berger (2004) proposes that the feeding of high concentrated diets early in life allows for the initiation of marbling deposition earlier than what would have occurred with more traditional management practices.

Sainz and Vernazza (2004) compared calf-fed steers (entered feedlot at weaning), short yearlings (finished after 4 months of irrigated pasture), and long yearlings (3 months of irrigated pasture, 9 months of dry range, and 3 months of irrigated pasture). When harvested at a constant backfat endpoint average DOF were 188, 158, and 94 for calves, short yearlings, and long yearlings, respectively (Sainz and Vernazza, 2004). Hot carcass weights were heaviest for long yearlings, followed by short yearlings and then calves (331, 315, 294 kg, respectively), indicating that a prolonged growing period increases the apparent mature size of the animal (Sainz and Vernazza, 2004). However, the percentage of USDA Choice or above carcasses were lower (30, 48, 46%, respectively) for long yearlings compared with the short yearlings and calf-feds (Sainz and Vernazza, 2004). Thus, prolonged grazing may decrease quality grade, either by impairing the ability of the animal to deposit intramuscular fat or by decreasing the time during which dietary energy supply is adequate for intramuscular fat deposition to occur (Sainz and Vernazza, 2004).

Hersom et al. (2004) compared the effects of previous body weight gain resulting from winter grazing programs on subsequent feedlot performance and carcass characteristics during the finishing phase. Hersom et al. (2004) concluded that grazing program did affect marbling score prior to the finishing phase. The initial differences in marbling scores were likely related to differences in energy intake and thus fat deposition during grazing (Hersom et al., 2004). Similar differences in marbling score have been observed between *ad libitum* access and restricted-fed steers (Sainz et al., 1995). However, when steers were finished to a common backfat end point, no differences in marbling score were reported (Hersom et al., 2004). Drouillard et al. (1991b), Sainz et al. (1995), and White et al. (1987) reported no differences in final marbling score when cattle from a variety of growing programs were harvested at a common backfat end point. Although no differences in finishing performance were observed, an increase in feedlot performance of the restricted steers would typically be expected (Hersom et al., 2004). Carstens et al. (1991) and Wright and Russel (1991) reported steers that had been restricted exhibited compensatory growth and gained faster while consuming similar amounts of feed compared to *ad libitum* access steers.

Several studies have been conducted to examine the effect of rate of winter gains or summer gains on carcass quality (Downs et al., 1998; Jordon et al., 1999; Klopfenstein et al., 2000; Lewis et al., 1990; Wilson et al., 1999). Winter pasture gains ranged from 0.19 to 0.72 kg/d while summer pasture gains were 0.57 or 0.84 kg/d (Klopfenstein et al., 2000). When adjusted to equal rib fat after grazing and finishing, there were no differences in quality grade for cattle grazed in the winter or summer (Klopfenstein et al., 2000). Therefore, Klopfenstein et al. (2000) concluded if cattle are fed to a common rib fat end point, the backgrounding program has little or no effect on marbling or carcass quality grade.

Wertz et al. (2002) evaluated the effect of weaning calves and growing them on a high forage diet compared to early-weaning and placing the calves on a high-concentrate diet immediately. The yearlings required 218 DOF to reach the desired marbling endpoint, while calf-fed heifers required 238 days on the finishing diet (Wertz et al., 2002). Yearlings grew faster (1.19 vs. 1.03 kg/d), but were less efficient (7.46 vs. 6.07 feed:gain) than calf-feds (Wertz et al., 2002). When marbling score was regressed against cumulative gain:feed, the calf-feds were 20% more efficient at any marbling endpoint compared to the yearling heifers (Wertz et al., 2002). At a common marbling endpoint the yearlings had an average yield grade of 3.85, while the calf-feds averaged 3.35 (Wertz et al., 2002). Similar results were reported by Wertz et al. in 2001; calves that were fed high energy diets deposited more marbling relative to backfat than heifers of the same genetics that were finished as long yearlings. The calf-feds produced high-quality carcasses with less subcutaneous fat cover while gaining more efficiently than heifers finished as yearlings (Wertz et al., 2002). Since the two groups of heifers were of similar genetics it appears that the nutrition/management systems influenced the relationship of marbling and backfat deposition (Berger, 2004). The data suggests that when calf-feds are managed so that they can express their genetic potential to marble, they will grade as well or better than yearlings (Berger, 2004).

Similar results were reported by Myers et al. (1999b); calf-feds immediately placed on a grain diet had greater marbling scores at lower backfat endpoints than normally weaned calves. Additionally, Myers et al. (1999b) reported an increased percent of early-weaned, grain-fed steers grading USDA Choice relative to early-weaned steers grown on pasture and then fed grain. Thus, it appears marbling deposition may be affected early in development, and furthermore that diet composition during the growing period may influence marbling deposition (Berger, 2004).

Region of Origin Effects on Feedlot Performance and Carcass Traits

It has been suggested that the origin of cattle plays a role or impacts the performance of an animal. However, there is limited published research on the effect of region of origin on feedlot performance and carcass traits. A study by Busby et al. (2008b) looked at calves from Midwest and Southeast states and the effect of origin on feedlot performance and carcass traits.

The Midwest cattle represented Iowa, Missouri, Indiana, Illinois and Minnesota, while the Southeast cattle represented Georgia, Virginia, Alabama, South Carolina, Mississippi, Tennessee, Florida, North Carolina, West Virginia and Kentucky (Busby et al., 2008b). The Midwest cattle tended to have better feedlot performance despite coming into the feedlot 5.1 kg lighter and 71.4 days younger (Busby et al., 2008b). Midwest cattle on average had heavier final weights (536.8 vs. 533.4 kg) and slightly greater ADG (1.46 vs. 1.44 kg/d) (Busby et al., 2008b). Southeast cattle had fewer health problems, a higher CAB acceptance rate and received a greater profit per head (Busby et al., 2008b). Southeast cattle had lower treatment costs ($5.01 vs. $7.38/head), morbidity (15.2% vs. 20.8%), and mortality rates (1.43%, vs. 1.76%) when compared to the Midwest cattle (Busby et al., 2008b). Southeast cattle averaged $11.32 per head more profit than the Midwest cattle (Busby et al., 2008b).

Season Effects on Feedlot Performance and Carcass Traits

Live animal performance is determined by two factors: genetic potential for growth and environmental conditions to which the animals are exposed (Ray et al., 1969). Environmental conditions include life-time nutrition, climate, disease prevalence, plus numerous management strategies/techniques (Ray et al., 1969). An important environmental factor influencing the performance of cattle is climate (Ray et al., 1969). Regression equations relating mean air temperatures or climatic stress to performance indicate that 40 to 60% of the seasonal variation in feedlot performance can be accounted for by climatic variables (Knox and Handley, 1973; Milligan and Christison, 1974; Ames et al., 1975; Johnson and Crownover, 1975). Seasonal variations in feedlot performance have been reported under both severe and relatively mild conditions (Elam, 1971; Milligan and Christison, 1974).

Ray et al. (1969) indicated both daily gain and efficiency of feed conversion are reduced by as much as 25% for those animals stressed from hot summer conditions commonly encountered in the desert southwest. Gains during the winter trials were 14 and 24% greater than those of animals fed during the summer, while feed required for each pound of gain was 7 and 19% less for cattle fed during the winter months vs. those fed in the summer (Ray et al., 1969). Cattle exhibit signs of heat stress when air temperatures reach 85º F (Cartwright, 1955). Thus, the decreased summer performance can be attributed to high ambient temperatures, although solar radiation and humidity contribute to heat stress as well (Ray et al., 1969).

In contrast, Birkelo et al. (1991) looked at seasonal variation and plane of nutrition of cattle fed in Northern Colorado. Maintenance requirements increase for livestock exposed to effective temperatures below the thermoneutral zone (Ames and Insley, 1975). Two variables which decrease effective temperature during the cold are dry bulb temperature and wind velocity, the combination of which is referred to as the wind-chill effect (Ames and Insley, 1975). Calculated maintenance requirements can increase by more than 40% for cattle fed in north-central Colorado as a result of seasonal changes in the environment (Johnson and Crownover, 1975). The increased energy requirements for cattle fed below the thermoneutral zone are acute response, shivering and [or] increased activity, and chronic response, metabolic rate acclimatization (Birkelo et al., 1991). Birkelo et al. (1991) reported acute cold stress, rather than chronically elevated metabolic rate, was the primary contributor to decreased performance during the "cold" months of the year. Gains for cattle during the winter period were lower (0.5 kg/d) while daily gains increased in the spring (1.1 kg/d) and summer (1.0 kg/d) (Birkelo et al., 1991). Seasonal variation in the environment affected requirements for weight maintenance, as evidenced by lower weight gains at a constant feed intake, but season did not affect thermoneutral maintenance energy requirements or fasting heat production (Birkelo et al., 1991). Birkelo et al. (1991) reported no interaction between season and plane of nutrition, although a lower temperature may have been required to affect steers on the high intake. This response would be expected if additional heat increment resulting from higher energy intake could offset thermoregulatory heat requirements (Birkelo et al., 1991). Thus, animals fed at a high energy intake would be affected less by cold than those fed smaller amounts of feed.

Kappel et al. (1972) reported cattle fed during the summer had greater gains, consumed more feed and were more efficient, while cattle fed during the winter had a greater dressing percentage ($P < 0.01$). However, in the second year of the trial cattle fed during the winter had greater gains, were more efficient and ate more feed (Kappel et al., 1972). These results suggest that the productive ability of the four groups of cattle varied and was confounded with any seasonal effects which might have been present (Kappel et al., 1972). Pontif et al. (1970) used cattle of similar type and condition and reported similar performance during summer and winter trials. Riggs (1966) reported no significant environmental effects on feedlot performance when six groups of Hereford cattle of similar background were fed at six climatologically different locations in Texas. These reports indicate environmental conditions may be of minor importance in the areas in which these experiments were conducted and suggests results were influenced more by the varying productive potential of the cattle than by environment (Kappel et al., 1972).

Koknaroglu et al. (2005) evaluated the effects of season cattle entered the feedlot on performance. No significant differences were reported for initial weight, days on feed or final weight (Koknaroglu et al., 2005). Daily feed intake was lowest for cattle started in the winter but cattle started in the summer had the greatest intakes (Koknaroglu et al., 2005). Lower feed intake in the winter might be explained by reduced water consumption and reduced digestibility of feedstuffs (Milligan and Christison, 1974). Season during which cattle were started on feed did not impact daily gains (Koknaroglu et al., 2005). Feed efficiency for cattle started in the winter was significantly better than for cattle started on feed in the summer and fall (Koknaroglu et al., 2005). The authors were surprised to observe cattle started during the winter had better conversion. An increase in gut motility and greater passage rate, thus a shortening of the exposure time of digesta with microbial degradation, would have been observed with cold exposure (Young, 1981). With cold there is stimulation of appetite, which may partially counteract the reduced level of production but not the reduced efficiency of utilization of dietary energy (Young, 1981). Other than feed efficiency observed in the winter, feed efficiency was better in seasons where day length was longer (spring and summer vs. fall) (Koknaroglu et al., 2005). The negative effect of shorter day length on feed efficiency could be possibly explained by increased glucocorticoid level (Leining et al., 1980) and stimulated fat accretion in shorter days (Mossberg and Jonsson, 1996). Cattle started on feed in the spring and fall were more profitable, but differences were not substantial (Koknaroglu et al., 2005). Bliss and Ward (1989) indicated on average, feeder cattle placed on feed in October and November and marketed in April and May were the most profitable. These placement and marketing months coincide with seasonally fewer feeder cattle and lower corn prices and seasonally greater slaughter cattle prices, respectively (Koknaroglu et al., 2005). Trapp (1989) also observed the most profitable feeding period occurred when cattle were placed on feed in December and harvested in May.

Another aspect of season is the effect of season of the year when cattle are harvested on carcass merit. In general, the percentages of the carcasses that grade low Choice or better increases in the spring and peaks around April (Berger and Faulkner, 2003). It then gradually decreases to a low point in October, and in November and December it starts to improve and the cycle is repeated (Berger and Faulkner, 2003).

Initially, season wouldn't appear to play a large part in the nutrition of feedlot cattle. The majority of feedlot diets have consistent nutrient profiles across seasons (Berger and Faulkner, 2003). However, when one considers that the nutrient profile consumed by cattle six to eight months prior to harvest may have a strong influence on quality grade, the effects of the season of the year may make sense (Berger and Faulkner, 2003).

Researchers have begun to understand the factors that regulate the conversion of preadipocytes that can fill and be detected as marbling (Berger and Faulkner, 2003). *In vitro* the fat soluble vitamins inhibit the conversion of preadipocytes to adipocytes, while Vitamin B_6 and Vitamin C stimulate differentiation (Berger and Faulkner, 2003). Adachi et al. (1999) reported that serum Vitamin A levels 4-6 months prior to harvest were significantly lower in high marbling steers compared to low marbling steers. The percentage of carcasses grading low Choice or better is at its lowest when cattle are harvested in the fall. These cattle will commonly enter the feedlot in late spring or early summer after grazing lush growing grasses or wheat pasture that can have 100,000-300,000 IU/kg Vitamin A activity (Dairy NRC, 1989). Kohlmeier and Burroughs (1970) found that steers coming off wheat pasture took over 84 days in the feedlot for Vitamin A blood levels to fall to those of steers entering the feedlot having been fed grass-legume hay. The 1996 Beef NRC recommends 455 IU/kg of Vitamin A activity for feedlot cattle. Galyean and Gleghorn (2001) summarized Vitamin A data from 13 consulting nutritionist that indicated their receiving diets averaged 1,660 IU/kg and typical finishing diets averaged 939 IU/kg. These concentrations of supplemental Vitamin A may be slowing adipocyte differentiation, especially in cattle entering the feedlot coming off lush grass that has high levels of Vitamin A (Berger and Faulkner, 2003).

Vitamin D may be just as important as Vitamin A in preventing adipocyte differentiation (Berger and Faulkner, 2003). Cattle can obtain Vitamin D from two sources, direct ultraviolet irradiation of the skin and by eating irradiated plants (Hidiroglou, et al., 1979). Cattle that grade poorly in the fall will have been exposed to maximum sunlight in the late spring and summer. This will increase circulating Vitamin D which can inhibit adipocyte differentiation at a time which could then contribute to the poor grading in the fall (Berger and Faulkner, 2003). However, there is conflicting research in the theory when the interaction of sex and the percentage of USDA Choice cattle is evaluated by month. The drop in the percentage of Choice cattle in the fall is much more dramatic for steers than for heifers (Anderson, 2001). Thus, more research is needed in the area to fully understand the role Vitamin D plays in preventing adipocyte differentiation.

Days on Feed Effects on Feedlot Performance and Carcass Traits

With the current marketing structure leaning towards value based marketing, the majority of cattle feeders target high quality beef. Although animal age, genetics, and other factors may influence U.S.D.A. Choice beef production, the most commonly used method to manipulate grade is the time the animal is fed a high concentrate diet (Gardner and Dolezal, 1996). Feeding management of cattle prior to harvest significantly affects carcass quality. Zinn et al. (1970a) and Campion and Crouse (1975) reported significant differences in carcass quality grade resulting from differences in time on feed (Tatum et al., 1980). In addition to carcass quality, longer feeding periods for cattle of a given starting weight typically increases final live weight, hot carcass weight, longissimus muscle area, subcutaneous fat thickness, and yield grade (Zinn et al., 1970a; Dolezal et al., 1982; Hicks et al., 1987; Van Koevering et al., 1995).

As time on feed is extended, there are increases in marbling score and quality grade (Moody et al., 1970; Zinn et al., 1970; Tatum et al., 1980; May et al., 1992; Duckett et al., 1993; Van Koevering et al., 1995). Regardless of the age or breed of cattle used, marbling deposition proceeds in a non-linear manner across time on feed (Duckett, 2000). There may be a plateau in marbling score after 112 days on a high concentrate diet (Duckett, 2000). Duckett et al. (1993) reported total lipid content in the longissimus doubled between 84 and 112 days on feed but did not differ from day 0 to 84 or from day 112 to 196. The increase in marbling fat content with increased time on feed appears to be due to an enlargement of the fat (adipocyte) cell with storage reservoirs (triglycerides) versus an increase in fat cell number, since the structural components of the cell (phospholipids) remained constant (Duckett, 2000). Similar results were observed by Nash et al. (2000) who utilized real-time ultrasound to monitor changes in intramuscular lipid content and predict quality grade across time on feed. The percent grading Choice increased from 20% at day 84 to 80% at day 100 and then remained constant to harvest at day 120 (Nash et al., 2000). However, Van Koevering et al. (1995) reported marbling score and the percentage of cattle grading U.S.D.A. Choice increased linearly with time on feed but at a decreasing rate. In contrast, Zinn et al. (1970) showed with calf-feds that marbling score and carcass grade increased significantly up to 240 days on feed. The data indicated that steers and heifers deposited intramuscular fat at a similar rate, and that the deposition of intramuscular fat is not a continuous process but proceeds in a step-wise pattern at 60 to 90-day intervals (Zinn et al., 1970).

Increasing the time cattle are on feed in effort to increase the percentage of U.S.D.A. Choice carcasses can have negative impacts on carcass cutability. Research shows that increasing the time on feed results in increased subcutaneous, internal, and intramuscular fat deposition; along with a linear increase in numerical yield grade (May et al., 1992; Duckett et al., 1993). Williams et al. (1989) observed that, as time on feed increased from 84 to 112 days, mean values for fat thickness and estimated percentage of kidney, pelvic, and heart fat, as well as the percentage of fat removed from the carcasses during hot fat trimming, increased (Gardner and Dolezal, 1996). In contrast, Moody et al. (1970) observed subcutaneous fat and the percentage of kidney, pelvic, and heart fat increased significantly between 56 and 84 days but not from 84 to 112 days on feed. Van Koevering et al. (1995) reported carcasses from cattle fed 147 days had significantly greater subcutaneous fat deposition, percentage of kidney, pelvic, and heart fat along with higher numerical yield grades than carcasses from cattle fed 105 days. Similar results were reported by Tatum et al. (1980), Hicks et al. (1987), Miller et al. (1987), and May et al. (1992).

Dressing percentage, HCW, and longissimus area may be increased with increasing days on feed (Moody et al., 1970; Zinn et al., 1970; Williams et al., 1989; and May et al., 1992). Van Koevering et al. (1995) reported hot carcass weights increased in a linear fashion with time on feed; this agrees with the linear responses reported previously by Hicks et al. (1987) and May et al. (1992). Dressing percentage was not altered by increasing time on feed in the 1995 study by Van Koevering et al. In contrast, Hicks et al. (1987) reported that dressing percentage increased linearly between 100 and 142 days on feed. Similar results were reported by Zinn et al. (1970) and Williams et al. (1989) that dressing percentage increased with time on feed. Williams et al. (1989) observed mean values for longissimus area increased with extended time on feed from 84 to 112 days. Moody et al. (1970) also reported a progressive increase in longissimus area as time on feed increased. However, this increase in ribeye size should probably be attributed to increases in live and carcass weights or size and not actual increases in muscularity (Gardner and Dolezal, 1996).

Contrasting results have been reported on the effect of time on feed on average daily gains. Zinn et al. (1970) reported that average daily gains increased with increasing time on feed up to 180 days. Average daily gains were lower for heifers than for steers, but were not significantly different (Zinn et al., 1970). Van Koevering et al. (1995) observed daily gains (carcass weight-adjusted basis) increased in a quadratic manner, whereas feed intake tended to increase linearly as cattle were fed longer. In contrast, Moody et al. (1970) reported no significant difference among days on feed for average daily gains or intake.

Feedlot Cattle Health

The cost of disease when cattle are sold on a live-weight basis is the sum of death loss, treatment cost, decreased feed efficiency, and decreased live weight (Larson, 2005). With the increasing percentage of cattle being priced on carcass merit grids, the impact of cattle disease on carcass traits has become of interest. Disease has the potential to affect not only carcass weight, but also the quantity, location and ratio of muscle, fat and water (Larson, 2005). Numerous studies have evaluated the effects of morbidity, defined as hospital visits per calf during the feeding period, on feedlot performance and carcass characteristics (Roeber et al., 2001). Busby et al. (2008a) looked at differences in performance between cattle never treated vs. those receiving a single treatment vs. those receiving two or more treatments. Cattle receiving two or more treatments had higher mortality rates, lower ADG, lower percentages of carcasses grading USDA Choice, higher percentages of dark cutters, and a higher percentage of yield grades 1 and

2, which, consequently resulted in lower net returns. Cattle treated two or more times returned $201.16/head less when compared to cattle never treated (Busby et al., 2008a). Similar negative carcass impacts were reported by Roeber et al., (2001) who documented decreased hot carcass weight, lower marbling score, lower dressing percent and lower adjusted fat thickness for cattle who experienced respiratory complications at least once in their life. In contrast, Waggoner et al. (2007) found no differences in hot carcass weight, fat thickness, longissimus muscle area, marbling score or yield grade between cattle not treated and those that were treated. They did report cattle never treated had higher ADG, less days on feed and a greater gross income (Waggoner, 2007). This discrepancy can be attributed to the differences in days on feed. By delaying harvest of calves treated for sickness, it may be possible to achieve carcass characteristics more similar to calves that remained healthy during the finishing period (Waggoner, 2007).

The Texas A&M Ranch-to-Rail program allows cow/calf producers to learn more about their calf crop and the factors that determine value beyond the weaned calf phase of beef production (McNeill, 1999). Over a five year period this program showed major room for improvement with average net returns per head ranging from a positive $307.03 per head to a negative $310.01, a $617.04 per head of opportunity (McNeill, 1999). Cattle that were treated not only incur medicine costs, but have lower gains, are less efficient, grade lower and have higher cost of gains. Healthy cattle had an average of $93.20/head more favorable return (McNeill, 1999). Medicine costs accounted for $31.97 with the remainder coming from reduced performance, increased feed cost of gain, higher interest expense and lower quality grades (McNeill, 1999). The Ranch-to-Rail program demonstrates the impact of health on the ability of cattle to express their genetic potential and the costs associated with sick cattle beyond the cost of medicine (McNeill, 1999).

Respiratory Disease

Bovine Respiratory Disease (BRD) is a multifactorial disease. It develops as a result of complex interactions between viruses, bacteria, Mycoplasma, physical, psychological, physiological, and environmental stress factors (Edwards, 1996). The BRD complex includes the bacterial pathogens *Mannheimia haemolytica*, *Pasteurella multocida*, and *Haemophilus somnus* and viral pathogens infectious bovine rhinotracheitis, bovine viral diarrhea, bovine respiratory syncytial, and parainfluenza type 3 (Ellis, 2001). Bovine Respiratory Disease is the most common feedlot disease accounting for approximately 75% of the morbidity and over 50% of the mortality in feedlots (Edwards, 1996). Bovine Respiratory Disease also known as "shipping fever" commonly occurs soon after arrival to the feedlot. Edwards (1996) reported that 70% of the respiratory cases occurred during the first 45 days in the feedlot. Newly received cattle encounter a number of stressors that may weaken the immune system. These stressors may include weaning, weather, transportation, commingling, feed/water deprivation during transport, and processing upon arrival to the feedlot (Galyean, et al., 1999). When these stressors act together to weaken the immune system, along with decreased feed intake upon arrival, the incidence of BRD increases as exposure to new disease pathogens occurs with commingling.

Bovine Respiratory Disease is the most costly feedlot disease. Annual losses to the US cattle industry are estimated to approach $1 billion, whereas preventative and treatment costs are over $3 billion (Snowder et al., 2007). Perino (1992) indicated that BRD is one of the few diseases that manifests its economic losses cumulatively; through the cost of treatment, lost performance and death loss along with increased labor and facility cost. The detrimental effects

BRD has on performance can be more devastating to the economic impact of BRD than medical costs or death loss. Gardner et al. (1999) reported that steers treated for BRD during the finishing phase had lower daily gains than untreated steers (1.53 vs. 1.47 kg/d). For the 150 day trial, steers treated for BRD averaged 2% lighter carcasses at harvest (Gardner et al., 1999). There have been similar reports in reduced gains among treated vs. non-treated cattle for respiratory disease by Cusack et al. (0.72 kg/d decrease in ADG for treated, 2007) and Van Donkersgoed et al. (1.11 vs. 1.25 kg/d, 1993). In contrast, there are studies that show ADG was not significantly reduced for treated vs. non-treated cattle (1.00 vs. 1.02 kg/d, Snowder et al., 2007; 2.83 vs. 2.85 kg/d Stovall et al., 2000). Final weights did not differ between steers treated once and those treated more than once (Gardner et al., 1999). However, for the entire trial the entire weight gain for those treated more than once was 21 kg less compared to those treated only once (Gardner et al., 1999).

Cattle treated for BRD have significant reductions in adjusted 12th rib fat and KPH fat percentage (Gardner al., 1999, Snowder et al., 2007). McNeill et al. (1996) and Gardner et al. (1999) reported that steers not treated for respiratory illness produced a greater percentage of USDA Choice carcasses than those steers that were treated. Heifers treated more than once for BRD had lower marbling scores than heifers never treated, which resulted in a 37.9% decrease in the percentage of carcasses grading USDA Choice or greater (Stovall et al., 2000). The decrease in marbling score and lower carcass weights results in a lower carcass value for cattle treated for BRD. Stovall et al. (2000) reported that when reduced carcass weight, decreased marbling score and medical costs were combined the gross value for heifers untreated, compared to heifers treated once or more than once netted $11.48/head and $37.34/head less, respectively.

Gardner et al. (1999) reported that steers treated for BRD only once gained faster, had more external and internal fat, had a higher dressing percent, a heavier carcass and a higher numerical yield grade than steers treated more than one time for BRD. Cattle that were treated more than once tended to have lower marbling scores than those treated only once. Roeber et al. (2001) found no difference in carcass traits between cattle that had never been treated and those treated only once. However, cattle that received two or more treatments for BRD had lower hot carcass weights, marbling scores, dressing percent, and yield grade when compared with cattle not treated for BRD (Roeber et al., 2001).

Digestive Disorders

Digestive disorders are less prevalent yet affect the feedlot industry significantly with the costs related to mortalities, medicine and depressed feedlot performance. Digestive disorders, primarily acidosis, are the second highest cause of death, accounting for 25.9% of all feedlot mortalities (Vogel et al., 1994). Acidosis and bloat are the two primary digestive disorders seen in the feedlot. Acidosis occurs with the ingestion of excessive amounts of readily fermented carbohydrates, commonly seen when adapting to a concentrate-rich diet (Owens et al., 1998). Acidosis generally is identified as a rumen pH below 5.0 or 5.2 (Glock et al., 1998). Animals experiencing acute acidosis have an increase in ruminal acidity and osmolality as acids and glucose accumulate; these can damage the ruminal and intestinal wall, decrease blood pH, and cause dehydration that proves fatal (Owens et al., 1998). In the case of chronic acidosis, feed intake and performance is typically reduced. Laminitis, polioencephalomalacia, and liver abscesses will often accompany acidosis (Owens et al., 1998). If an animal recovers from acidosis their nutrient absorption may still be retarded throughout the feeding phase (Owens et al., 1998).

Bloat is caused by various factors and interactions that include management, feed, animal and microbial functions (Cheng et al., 1998). While the use of feed additives and the improvements in management practices have helped to reduce the occurrence of bloat it has not eliminated the issue. Optimizing utilization of cereal grains while maintaining normal rumen function and animal health continues to be one of the major challenges faced by the feedlot industry (Cheng et al., 1998). Bloat occurs with the ingestion of large amounts of rapidly fermented cereal grain and destabilization of the microbial populations of the rumen (Cheng et al., 1998). An abundance of rapidly fermented carbohydrate allows acid-tolerant bacteria to proliferate and produce excessive quantities of fermentation acids (Cheng et al., 1998). As a result, ruminal pH becomes exceedingly low, and this impairs rumen motility (Cheng et al., 1998). If the ruminal conditions prevent normal contractions from occurring in the reticulo-rumen or if movement of free gas through the cardia or esophagus is obstructed, bloat occurs (Clarke et al., 1974). As the gas accumulates, the expanding rumen exerts pressure on the diaphragm and lungs, impairs respiration, and ultimately leads to death (Bartley et al., 1975).

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CHAPTER 2 - SEASON OF ARRIVAL AND GEOGRAPHIC REGION OF ORIGIN AFFECT FEEDLOT PERFORMANCE, HEALTH, AND CARCASS TRAITS OF ANGUS STEERS

INTRODUCTION

Season of arrival at the feedlot (Ray et al., 1969; Elam, 1971; Birkelo et al., 1991) and region of origin (Busby et al., 2008; USDA, 2008) may impact feedlot health, performance, and carcass traits. These factors have been quantified independently, but there is little documentation of their combined and interactive effects within a commercial production setting. Morbidity reduces performance and quality grade (Gardner et al., 1999; Reinhardt et al., 2009), but there is little documentation on the effects of morbidity on quality grade independent of its effect on carcass fatness. As feedlot cattle fatten, a greater proportion of their daily carcass gain goes to fat deposition (Dinkel et al., 1969), and because greater carcass fat is consistent with greater marbling score (Reinhardt et al., 2009) it is often assumed that higher grading cattle must have reduced feedlot performance, but there is little documented evidence of this relationship.

Objectives of this research were to document impacts of various animal and non-animal factors on feedlot performance, health, and carcass traits in Angus steers and to correlate quality and yield grade components of carcass with live performance.

MATERIALS AND METHODS

Angus steers (n = 17,919) fed at a single commercial feedlot in southwestern Kansas between 1997 and 2007 were used to correlate various non-animal and animal-specific characteristics with performance, health, and carcass traits. Animal care procedures were in compliance with the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999).

Non-animal factors of interest were season of arrival and geographic origin. Season of arrival was categorized as winter (December, January, and February), spring (March, April, and May), summer (June, July, and August), or fall (September, October, and November). Regions were south central (SC; Texas, Oklahoma, and New Mexico), central (C; Colorado and Kansas), north central (NC; Montana, Nebraska and Wyoming), and southeast (SE; Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia). Cattle arriving from each region averaged the following shipping distances to the feedyard: central = 45 km; south central = 300 km; north central = 336 km; southeast = 503 km.

Animal factors of interest were health status, ADG, quality grade, and yield grade. Health status categories were no treatments, single treatment, 2 treatments, and more than 2 treatments for respiratory or other diseases. Animals were also grouped by rate of gain (<1.36, 1.36 to 1.55, 1.56 to 1.81, and >1.81 kg/d), quality grade (Prime, Choice, Select, Ungraded), and yield grade groups (yield grade 1 and 2, yield grade 3, and yield grade 4 and 5). Groups with fewer than 30 representative animals were removed from consideration prior to statistical analysis.

Cattle were fed at a commercial feedlot near Garden City, KS, with a one-time capacity of roughly 3,000 animals. Animals were all fed in similar outdoor, dirt-floor pens that used concrete fence-line bunks. Animals were provided with 19 to 23 m^2 of pen area and 22 to 30 cm of bunk space. Average estimated energy content (based on formulations) of the finishing diet across all years was 2.07 Mcal of NE_m/kg DM feed and 1.39 Mcal of NE_g/kg DM feed. Crude protein content prior to 2003 averaged 13.5% but then increased to 15.5% due to inclusion of wet distillers grains. The implant program across all years consisted of a mild estrogenic implant (Ralgro; Intervet/Schering-Plough Animal Health, Desoto, KS) upon arrival followed by a combination estrogenic/androgenic terminal implant (Revalor-S; Intervet/Schering-Plough Animal Health, Desoto, KS; Synovex Plus, Fort Dodge Animal Health, Overland Park, KS) administered approximately 70 d before anticipated date of harvest.

Most calves had been fully preconditioned (including weaning, vaccination, revaccination, deworming, feed bunk training, water tank training) for a minimum of 30 d prior to delivery to the feedlot. Some groups were placed in backgrounding lots or on pasture at or near the ranch of origin for an extended period (60 to 150 d) with their original ranch herdmates. Cattle were not commingled with calves from other ranch sources prior to delivery to or following arrival at the feedlot. These conditions resulted in low rates of morbidity and mortality compared to many commercial feedlot situations which feed non-backgrounded calves. Animals were observed daily for morbidity by feedlot personnel. Animals were removed from home pens when they showed clinical signs of respiratory disease including lethargy, ocular or nasal discharge, or lack of appetite. All health evaluators were professional feedlot personnel. Of the animals removed for clinical symptoms, those exhibiting rectal temperatures ≥ 39.7°C received antimicrobial therapy.

Animals were visually evaluated for degree of finish by the general manager of the feedlot 60 to 80 d after administration of the terminal implant. Animals determined to be adequately finished (approximately 1.27 cm fat thickness or estimated yield grade 3) were shipped to the abattoir. Animals not shipped with the first marketing group were evaluated for finish again 14-21 d later, and those meeting the criteria were shipped. A third group was subsequently shipped an additional 14-21 d after the second marketing group.

Nonconforming data, as determined by outlier analysis, were removed from consideration. Outliers were determined by first calculating a test statistic from the equation:

$$z = (x - \mu)/\sigma$$

where x = individual value, μ = mean of the population, and σ = standard deviation of the population

Individual values (not entire data line for an individual animal) were eliminated from analysis when:

$$|z| \geq 2.5$$

Remaining data are summarized in Table 1.

Data for continuous dependent variables were analyzed with the MIXED procedure of SAS version 9.1 (SAS Institute, Cary, NC) with individual animal as the experimental unit. To account for differences in yard conditions among years, placement year was included as a random variable. Linear and quadratic contrast statements were included for independent variables with more than 2 incremental levels, and contrast were conducted to compare the Central region vs. the South East region, the Central region vs. all other regions, and cattle which arrived in the Fall and Winter vs. those which arrived in the Spring and Summer. For categorical or binary dependent variables, the LOGISTIC procedure of SAS version 9.1 was performed. Effects were considered significant when the *P*-value fell below the protected F test of $P < 0.01$.

In attempting to analyze the effects of Region and Season, there existed 3-way interactions between Region, Season, and initial BW, which confounded analysis of these independent variables. Analysis of Region could not be considered within each Season due to insufficient observations for Spring and Summer arrivals from the North Central and South East

Regions. For this reason, only cattle arriving in the Fall and Winter were included in analysis of Region; in the same way, only cattle in the C and SC Regions were included in analysis of Season. Also, the interaction of initial BW with the variable of interest was often significant, resulting in additional analyses of the variable of interest within 3 distinct weight classes: 295-330 kg, 331-375 kg, and > 375 kg. By breaking the data into these groups, differences in initial weight between categories of the variable of interest were reduced or eliminated.

Because initial weight was strongly associated with number of treatments, and because the effects of number of treatments were documented on performance, yield grade, and quality grade, morbid cattle were eliminated from analyses of some variables. Because the yield grade was associated with quality grade, yield grade 1 and 2 cattle were eliminated from analysis of some variables.

RESULTS AND DISCUSSION

Region of Origin

There was a much greater number of steers which originated in the Central region than the other regions (65% C, 22% SC, 7% SE, and 6% NC). Steers from the SE and NC regions had the greatest and lightest initial BWs, respectively (initial BW = 396, 323, 371, and 343 kg for SE, NC, C, and SC, respectively; $P < 0.01$; table 2). In the 295-330 kg group the SC steers had the greatest number of treatments (number of treatments = 0.42 vs. 0.17, 0.14, and 0.17 for SC, SE, NC, and C, respectively; $P < 0.01$; table 3), but in the other weight groups there were no great differences between regions (tables 4 and 5). Busby et al. (2008) reported that southeast and south central steers required the greatest number of treatments per animal placed in feedlots in southwestern Iowa. The lack of a consistent pattern of morbidity from a single region, especially in the heavier steers, may be due to the fact that all of the steers in the present analysis were pre-conditioned and backgrounded prior to shipment to the feedyard, giving them greater ability to ward off disease, as indicated by the overall morbidity and mortality rates of 8.9 and 0.8% (Table 1). Reinhardt et al. (2009) reported inverse relationships between BW at feedlot arrival and morbidity, mortality, and post-harvest lung pathology, and Macartney et al. (2003) reported that vaccination and feeding prior to shipment to the feedyard reduced likelihood of respiratory disease by 78%.

Generally, steers from the SC region had the poorest ADG (1.50 vs. 1.64, 1.64, and 1.70 kg/d; $P < 0.01$), and steers from the C region had the greatest quality grade (2.77 vs. 2.63, 2.64, and 2.69; $P < 0.01$). Contrary to the present study, Busby et al. (2008) reported low quality grade in steers from the southeast. The intention of the feedyard management was to market cattle in the present dataset at a visually evaluated, fat-constant endpoint, and this held true in all but the heaviest weight group, in which yield grade was highest in the NC steers and lowest in the SC steers (3.23, 2.98, 2.89, and 2.84 for NC, SE, C, and SC, respectively; $P < 0.01$). Interestingly, quality grade among this heavy group did not follow the yield grade trend, with C and SE steers having the highest and lowest quality grades, respectively ($P < 0.01$).

Season of Entry into Feedlot

The majority of steers analyzed arrived during the Fall or Winter (12% = Spr, 12% = Sum, 33% = F, 43% = W). Steers placed on feed during the winter and fall had the lightest initial BW, and those placed during summer and spring had the greatest BW upon arrival ($P < 0.01$, Table 6). This matches with the known backgrounds of cattle within this population; most were spring-born calves, some of which were shipped to the feedyard after weaning in the fall, and others were backgrounded for either a short (30 to 60 d) or extended (60 to 150 d) period. Koknaroglu et al. (2005) reported that cattle entering the feedyard during fall months tended to be lighter than those entering during the summer. In the light and medium BW groups summer-arriving steers had the greatest final BW and HCW, but in the heavy group the Spring-arriving steers had the greatest final BW and HCW; fall steers had the lightest final BW when evaluated in the light and medium weight classes ($P < 0.01$). Conversely, Koknaroglu et al. (2005), who evaluated a much larger data set (275,598 animals) from a different region of the United States (Iowa) 10 yr earlier (1988 to 1997), saw no significant differences in final BW between placement seasons. Fall-placed steers also had the lowest ADG of all seasons ($P < 0.01$). Contrary to the present study, season of entry did not affect ADG in the study by Koknaroglu et al. (2005). Birkelo et al. (1991) reported that ADG decreased dramatically during the winter feeding period compared with summer and fall months for cattle fed in a Colorado feedlot, although Riggs et al. (1966) and Pontif et al. (1970) observed no significant differences in ADG for cattle fed under different climatic conditions or seasons. Ray et al. (1969) reported that ADG during winter trials were 14 and 24% greater than during summer trials; however, these studies were conducted in southern Arizona. Hicks et al. (1990) summarized data (n = 296,367 animals) from a commercial feedyard in western Oklahoma and reported that peak DM intake was greatest for calves that entered the feedlot during the winter and lowest for calves that entered the feedlot during the summer, which may be partially a response to climatic conditions.

Steers that arrived during the summer had the greatest ($P < 0.01$) number of treatments per animal among each weight class. Contrary to the present study, Hicks et al. (1990) reported that calves arriving during the fall had the greatest incidence of both morbidity and mortality compared to other seasons. Increased daily temperature variation (range of minimum to maximum) and increased wind velocity, which are common during the fall and winter in southwest Kansas (for the period of this analysis, fall and winter combined: avg maximum temperature = 14.2ºC; avg minimum temperature = -0.9ºC; avg daily temperature range = 15.1ºC; avg wind velocity = 13.9 kph), have been associated with greater incidence of respiratory disease (Speidel et al., 2008), but did not greatly affect morbidity rates in fall- or winter-placed steers.

In the light and medium weight classes, quality grade was highest for summer-placed steers and among the lowest for spring-placed steers ($P < 0.01$) in all weight classes; accordingly, summer-placed steers also had among the highest yield grades within these same weight groups. Berger and Faulkner (2003) reported that the percentage of carcasses that grade Choice or greater increases when cattle are harvested in the spring (potentially fall-placed calves and winter-placed yearlings) and then gradually decreases to a low point in the fall (spring-placed cattle). However, the present dataset does not agree with those findings. Potentially difficult environmental conditions that resulted in lower-than-average ADG for fall placements could have contributed to the observed reductions in quality grade in the present dataset. There were minimal differences in percentage of carcasses grading Choice among steers in the heaviest weight class. This may indicate that various nutritional or environmental factors which affected performance in the feedyard did not greatly affect marbling deposition.

Body Weight Upon Arrival

The dataset consist exclusively of weaned calves which had been previously backgrounded prior to shipment to the feedyard, resulting in slightly heavier BW on arrival than a conventional calf population (85% ≥ 295 kg). There were linear and quadratic relationships ($P < 0.01$; table 10) between initial BW and final BW, ADG, d on feed, number of treatments, and HCW which concurs with previous studies (Reinhardt et al., 2009; Zinn et al., 2008). Zinn et al.

(2008) reported that shrunk initial BW explained 39 and 25% of final BW and ADG, respectively.

There were few strong relationships between initial BW and measures of quality grade or yield grade. These cattle were intentionally marketed at a visually estimated common backfat, as identified by a skilled cattle evaluator, which explains the lack of difference in yield grade (and subsequent quality grade) based on initial BW.

Number of Times Treated

Only 7.7% of the cattle were treated with a fairly equal proportion treated once, twice and 3 or more times (table 11). Initial BW, final BW, and HCW decreased in linear and quadratic manners with increasing number of times treated ($P < 0.01$; table 11). Initial BW was 30 to 40 kg lighter in treated cattle than cattle requiring no treatment, in accord with data reported by Reinhardt et al. (2009) but contrary to the results of Waggoner et al. (2007) and Gardner et al. (1999). Those studies utilized populations with more uniform initial BW, reducing the likelihood of finding differences based on a single, non-controlled factor. Faber et al. (1999) reported an inverse relationship between age at feedlot entry and percentage of calves requiring disease therapy. McAllister et al. (2008) reported that arrival weight was positively correlated with days to disease onset, which may be an indicator of the cattle's ability to overcome the stress of the transition period. Average daily gain decreased linearly ($P < 0.01$, Table 11) with increasing number of times treated for all causes of morbidity. Similar reductions in ADG were reported by Gardner et al. (1999), McNeill et al., (1996), and Reinhardt et al. (2009). Although Jim et al. (1993) and Wittum et al. (1996) reported no significant differences in ADG for cattle that were or were not identified as requiring treatment for respiratory disease, Wittum et al. (1996) reported a significant reduction in ADG for steers possessing lung lesions as a sign of previous respiratory disease regardless of clinical symptoms. Waggoner et al. (2007) also reported that cattle requiring 1 or more treatments for respiratory disease required a greater number of days on feed to reach market weight.

Hot carcass weight, quality grade, and yield grade all decreased linearly with increasing number of times treated. These data concur with those reported by Gardner et al. (1999), Roeber et al. (2001) and Reinhardt et al. (2009), who noted decreasing HCW as number of treatments increased. Although Waggoner et al. (2007) reported no differences in HCW for cattle that were or were not observed to be morbid, it is important to realize that cattle in that study were fed to a common final BW rather than common days on feed. As number of treatments increased, the percentage of cattle grading USDA Choice decreased ($P < 0.01$). The percentage of carcasses qualifying for a Premium Choice program was greatest for cattle that were not treated ($P < 0.01$). McNeill et al. (1996), Gardner et al. (1999), and Reinhardt et al. (2009) also showed that cattle receiving treatment for morbidity had lower marbling scores, resulting in a lower percentage of USDA Choice carcasses. Stovall et al. (2000) reported that heifers treated more than once had a 37.9% reduction in carcasses grading USDA Choice or greater. When only cattle marketed at yield grade 3 were included in the analysis for quality grade, the effects of number of times treated was reduced. When all cattle are included, there are differences of 4.5 and 11.9 percentage units of Choice between non-treated and cattle treated ≥ 3 times; when only yield grade 3 cattle are considered these differences drop to 2.4 and 9.1 units, suggesting that a portion, though not all, of the reduction in quality grade due associated with morbidity is due to reduction in degree of finish. Treated cattle had lower yield grades than non-treated cattle ($P < 0.01$), and the percentage of yield grade 1 and 2 carcasses increased linearly with number of times treated ($P < 0.01$). Similarly, Stovall et al. (2000), Roeber et al. (2001), and Reinhardt et al. (2009) all reported that cattle that did not require treatment had a greater percentage of yield grade 3, 4, and 5 carcasses.

Waggoner et al. (2007) reported no significant differences in quality or yield grade between treated and non-treated cattle, but in that study cattle were marketed at a common external fat-constant endpoint, which allowed morbid cattle to compensate for reduced fat deposition during the disease process with extended d on feed to achieve finish level and marbling scores similar to those of non-morbid cattle. Snowder et al. (2007) also reported no effect of morbidity on fat thickness or marbling score, but cattle utilized in that study were of low risk of developing severe respiratory disease, and no indication was given as pertaining to the number of treatments morbid cattle received.

Effects of Quality Grade

Because this analysis included only Angus cattle which had not been treated for disease and which were purposely, marketed at an individually identified fat-constant endpoint, 72% graded Choice or Prime. Cattle that had greater quality grade had greater initial BW (linear, $P < 0.01$), final BW, ADG, HCW, and yield grade (linear and quadratic $P < 0.01$), and reduced number of d on feed (quadratic, $P < 0.01$; Table 15). Mader et al. (2009) reported no significant correlations between DM intake and back fat or marbling score. However, that study used a small number of uniform cattle, whereas the present study attempted to draw inferences from a much more heterogeneous population. It is conceivable that a certain class of cattle (combination of origin, disposition, disease status, and age as estimated by initial BW) may consume more feed, gain more rapidly, and deposit marbling more rapidly than cattle of a different class. Conversely, Arnold et al. (1991) reported positive correlations between marbling and ADG in Hereford steers, and Vieselmeyer et al. (1996) reported numerically, but not significantly greater feedlot ADG and DMI in high- vs. low-marbling Angus cattle. If this observed increase in ADG was truly a function of increased energy intake (as opposed to increased efficiency of energy use), an increase in quality grade would be a logical result as well. Zinn et al. (2008) demonstrated that although DMI, ADG, and final BW are positively correlated with initial BW (r = 0.75, 0.53, and 0.68), they improved the estimate of final BW by adding a function of the "quality" of the cattle or the ADG of an animal relative to the average of the group. They then estimated retained energy (strongly related to total carcass fat content, e.g. marbling and external fat) using a daily gain-adjusted final BW, suggesting that cattle types with greater ADG will also deposit fat at a greater rate. NRC (1984, 1996) also suggest that the rate of fat deposition increases with increasing ADG.

There is little difference in ADG, final BW, and HCW between cattle which grade Prime, Choice, or Select, but performance dramatically drops for those cattle which were ungraded. The number of treatments was roughly double for ungraded cattle vs. cattle which graded Prime or Choice (0.11 vs. 0.05 and 0.06 for ungraded vs. Prime and Choice, respectively) which may suggest part of the performance difference based on quality grade. However, when only non-treated cattle with yield grade 3, 4, and 5 were included in the analysis (table 16), differences in final BW (quadratic $P = 0.04$; linear $P = 0.07$), ADG (linear and quadratic, $P < 0.01$), and HCW (linear, $P = 0.12$; quadratic $P = 0.09$) were still present, but were greatly diminished.

Effects of Yield Grade

Although 39% of the cattle fell outside the target marketing endpoint of yield grade 3, only 2% were either yield grade 1 or 5. Cattle with greater final yield grade had fewer number of treatments (linear and quadratic, $P < 0.01$). In cattle not treated for disease, cattle with greater yield grade had greater final BW, ADG, d on feed, and HCW (linear, $P < 0.01$; table 17), and greater quality grade (linear and quadratic, $P < 0.01$). Klopfenstein et al. (2000; summarizing data from Gwartney et al., 1996) reported that marbling score increased with increasing fat thickness in Angus steers and heifers, that the correlation coefficient and slope of the relationship were higher for offspring of high-marbling bulls vs. low-marbling bulls.

Much of the increase in quality grade occurred between yield grade 1 and 2 cattle and yield grade 3 cattle, and very little change was seen between yield grade 3 and yield grade 4 and 5 cattle. Percentage of cattle which graded Choice increased 16.1 percentage units between yield grade 1 and 2 cattle and yield grade 3 cattle, but only increased an additional 1.6 percentage units in yield grade 4 and 5 cattle. Similarly, Garcia et al. (2008) found that the combined percentages of Prime and Choice carcasses increased 28 percentage points from yield grade 1 and 2 carcasses to yield grade 3 carcasses, and only 8 additional percentage points in yield grade 4 and 5 carcasses. Wertz et al. (2001) reported a positive, linear relationship between external fat and marbling deposition. However, Bruns et al. (2004) demonstrated that whereas marbling accumulates in a linear manner with increasing HCW, external fat increases at an accelerating rate with increasing HCW.

Rate of Gain in the Feedlot

As discussed previously, disease impedes feedlot performance and quality grade; therefore, morbid cattle were excluded from this analysis.

Generally speaking, more rapidly gaining cattle had greater initial BW, final BW, ADG, HCW, and yield grade and had lower d on feed than slower gaining cattle (linear and quadratic $P < 0.01$; table 18). Although DM intake was not recorded for individual animals, the increase in yield grade with increasing ADG is possibly due to increased DM consumption and, hence, net energy consumption. Zinn et al. (2008) reported positive correlations between ADG and initial

BW, final BW, and DM intake. These authors also calculated a predictive relationship between ADG and retained energy. Conversely, although Mader et al. (2009) found positive correlations between ADG and final BW and HCW, they reported moderate, negative correlations between ADG and marbling score and back fat. However, the Mader et al. (2009) study used a relatively small, relatively uniform cattle population, whereas the Zinn et al. (2008) and present studies used large commercial feedyard databases of diverse cattle populations.

Quality grade increased with increasing ADG in only the light and medium weight groups (linear and quadratic, $P < 0.01$); there was no relationship of ADG with quality grade in the heavy group (linear and quadratic, $P = 0.94$ and 0.82). Marbling deposition appears to be under less influence of nutritional, management or environmental factors in yearlings vs. calves. Bruns et al. (2005) demonstrated that administration of a combination implant had similar effects on performance when administered at 309 vs. 385 kg, but had much greater negative impact on rate of marbling deposition when administered at the earlier stage of growth than if administration was delayed. Anderson et al. (2005), Sainz and Vernazza Paganini (2004) and Choat et al. (2003) reported that severe nutrient restriction of young calves reduced marbling deposition vs. non-restricted calves even when harvested at a common fat endpoint, suggesting that various forms of nutritional stress may diminish ultimate quality grade when all cattle are marketed at a common fat endpoint. Also, these studies suggest the converse: that elimination of nutritional stress early in development allows the animal to deposit marbling up to its genetic potential.

With all data included yield grade was positively correlated to quality grade (Prime = 4, Choice = 3, Select = 2, ungraded = 1; r = 0.167; table 22), and when yield grade 4 and 5 carcasses were eliminated from consideration the correlation improved slightly (Prime = 5, Premium Choice = 4, Low Choice = 3, Select = 2, ungraded = 1; r = 0.192). This agrees with Wertz et al. (2002) and Brethour (2000) who reported positive correlations between subcutaneous fat and marbling. Number of treatments per animal was negatively correlated with quality grade and ADG (r = -0.070 and -0.152, respectively), which is consistent with the reports of Gardner et al. (1999) and Reinhardt et al. (2009). Initial BW was negatively correlated with number of treatments (r = -0.104) and positively correlated with ADG, final BW, and HCW (r = 0.185, 0.425, and, 0.405, respectively), which agrees with previous reports (Zinn et al., 2008; Reinhardt et al., 2009), but initial BW had nearly no relationship with quality grade or yield grade (r = 0.035 and 0.021, respectively), which is inconsistent previously reported findings (Reinhardt et al., 2009).

IMPLICATIONS

The strong inter-relationship between ADG, yield grade, and quality grade suggests that beef producers who are attempting to raise and market highly marbled beef do not need to choose between the genetics for performance vs. genetics for marbling, but instead can select for high performance cattle with high marbling potential. If they then reduce opportunities for nutritional stress (e.g. nutrient restriction, health challenges), and then ensure that the cattle are fed to their target fat content endpoint producers will more consistently achieve both excellent performance and quality grade.

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Table 2.1 Selected live and carcass attributes for Angus steers fed in a single Kansas feedlot from 1997-2007. (n = 17,919)

Trait	Mean	Minimum	Maximum	SD
Initial BW, kg	358	184	522	62.7
Final BW, kg	581	446	702	45.7
ADG, kg/d	1.64	0.79	2.43	0.30
d on feed	135	31	248	35.7
Mortality, %	0.8	-	-	-
d fed prior to death	76	4	222	46
Percentage treated[1]	8.9	-	-	-
HCW, kg	374	221	515	30.7
USDA Quality grade[2]	2.71	0	4	0.57
Prime, %	2.4	-	-	-
Premium choice[3], %	19.7	-	-	-
Choice, %	69.5	-	-	-
Select, %	27.2	-	-	-
Ungraded, %	0.9	-	-	-
USDA Yield grade	2.86	1	5	0.66
Yield grade 1 and 2, %	26.1	-	-	-
Yield grade 3, %	60.7	-	-	-
Yield grade 4 and 5, %	13.2	-	-	-

[1] Treated: Includes any health treatments received while at feedlot.
[2] Quality grade: 4 = Prime; 3 = Choice; 2 = Select; 1 = Ungraded.
[3] Premium choice: Qualified for Certified Angus Beef or Sterling Silver (≥ $Modest^0$ marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.2 Main effect of region of origin on feedlot performance, health, and carcass traits for Angus steers, arriving in the Fall and Winter fed in a single Kansas feedlot from 1997-2007 (all weights included).

	Region of Origin[1]					*P*-value			
Trait	SE	NC	C	SC	SEM[2]	Region	Initial BW × Region	C vs. others	C vs. SE
n	1,316	994	11,475	3,919					
Initial BW[3], kg	396	323	371	343	2.9	< 0.01	-	< 0.01	< 0.01
Final BW[3], kg	578	579	585	563	1.6	< 0.01	< 0.01	< 0.01	< 0.01
ADG[3], kg/d	1.64	1.64	1.70	1.50	0.011	< 0.01	< 0.01	< 0.01	< 0.01
d on feed[3]	142	148	142	145	0.9	< 0.01	< 0.01	< 0.01	0.98
Number of treatments[4]	0.43	0.19	0.18	0.34	0.038	< 0.01	< 0.01	< 0.01	< 0.01
HCW[3], kg	371	371	375	365	1.0	< 0.01	< 0.01	< 0.01	< 0.01
HCW ≥ 454 kg, %	1.1	0.4	0.5	0.4	0.25	1.00	0.99	0.93	0.96
USDA Quality grade[3,5]	2.64	2.69	2.77	2.63	0.019	< 0.01	0.26	< 0.01	< 0.01
Prime[3], %	2.5	0.7	2.4	1.7	0.58	0.22	0.49	0.96	0.95
Premium choice[3,6], %	14.7	15.6	21.0	13.2	1.52	< 0.01	0.26	< 0.01	< 0.01
Choice[3], %	60.7	67.9	72.8	60.8	1.76	< 0.01	0.08	< 0.01	< 0.01
Select[3], %	34.7	31.4	24.1	36.3	1.70	< 0.01	0.59	< 0.01	< 0.01
Ungraded[3], %	2.1	0.1	0.8	1.2	0.37	< 0.01	0.48	0.97	< 0.01
USDA Yield grade	2.73	3.09	2.88	2.85	0.024	< 0.01	< 0.01	0.58	< 0.01
Yield grade 1 and 2, %	35.2	13.9	25.0	27.8	1.64	< 0.01	< 0.01	0.21	< 0.01
Yield grade 3, %	53.4	63.4	61.1	58.3	1.87	< 0.01	< 0.01	0.04	< 0.01
Yield grade 4 and 5, %	11.4	22.8	14.0	13.9	1.27	< 0.01	< 0.01	0.01	< 0.01

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.3 Main effect of region of origin on feedlot performance, health, and carcass traits for Angus steers, arriving in the Fall and Winter with arrival weight of 295-330 kg fed in a single Kansas feedlot from 1997-2007.

	Region of Origin[1]					*P*-value		
Trait	SE	NC	C	SC	SEM[2]	Region	C vs. others	C vs. SE
n	55	74	1,054	720				
Initial BW[3], kg	318	316	315	314	1.4	< 0.01	0.30	0.03
Final BW[3], kg	531	557	561	544	6.0	< 0.01	< 0.01	< 0.01
ADG[3], kg/d	1.66	1.62	1.71	1.38	0.037	< 0.01	< 0.01	0.11
d on feed[3]	127	153	145	171	2.9	< 0.01	< 0.01	< 0.01
Number of treatments[4]	0.17	0.14	0.17	0.42	0.163	< 0.01	0.35	0.99
HCW[3], kg	340	357	360	355	3.9	< 0.01	< 0.01	< 0.01
USDA Yield grade	2.67	2.96	2.83	2.84	0.092	0.12	0.86	0.09
Yield grade 1 and 2, %	40.9	27.2	29.3	26.4	6.46	0.17	0.74	0.14
Yield grade 3, %	48.1	50.3	57.6	62.6	7.25	0.04	0.26	0.23
Yield grade 4 and 5, %	11.0	22.5	13.1	11.1	4.79	0.03	0.66	0.60

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments per animal received while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.4 Main effect of region of origin on feedlot performance, health, and carcass traits for Angus steers, arriving in the Fall and Winter with arrival weight of 331-375 kg fed in a single Kansas feedlot from 1997-2007.

	Region of Origin[1]					*P*-value		
Trait	SE	NC	C	SC	SEM[2]	Region	C vs. others	C vs. SE
n	476	1,002	8,477	3,219				
Initial BW[3], kg	356	356	355	351	1.3	< 0.01	0.57	0.36
Final BW[3], kg	562	563	580	566	3.8	< 0.01	< 0.01	< 0.01
ADG[3], kg/d	1.66	1.70	1.76	1.49	0.027	< 0.01	< 0.01	< 0.01
d on feed[3]	125	124	128	146	1.8	< 0.01	< 0.01	0.04
Number of treatments[4]	0.31	0.34	0.13	0.30	0.072	< 0.01	< 0.01	0.01
HCW[3], kg	360	360	372	366	2.5	< 0.01	< 0.01	< 0.01
USDA Yield grade	2.78	3.05	2.87	2.88	0.052	< 0.01	0.20	0.09
Yield grade 1 and 2, %	32.5	18.5	31.0	27.2	3.54	< 0.01	0.14	0.14
Yield grade 3, %	55.9	59.0	55.8	61.1	4.12	0.12	0.61	0.39
Yield grade 4 and 5, %	11.6	22.5	13.2	11.7	2.92	< 0.01	0.60	0.29

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest[0] marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.5 Main effect of region of origin on feedlot performance, health, and carcass traits for Angus steers, arriving in the Fall and Winter with arrival weight of > 375 kg fed in a single Kansas feedlot from 1997-2007.

	Region of Origin[1]					*P*-value		
Trait	SE	NC	C	SC	SEM[2]	Region	C vs. others	C vs. SE
n	236	300	4,131	881				
Initial BW[3], kg	416	415	415	417	2.6	0.61	0.52	0.80
Final BW[3], kg	606	601	602	587	3.3	< 0.01	0.01	0.30
ADG[3], kg/d	1.73	1.78	1.73	1.58	0.026	< 0.01	0.01	0.84
d on feed[3]	110	106	109	109	1.5	0.13	0.38	0.49
Number of treatments[4]	0.20	0.11	0.12	0.16	0.046	0.25	0.19	0.09
HCW[3], kg	388	384	387	380	2.1	< 0.01	0.02	0.57
USDA Yield grade	2.98	3.23	2.89	2.84	0.042	< 0.01	< 0.01	0.04
Yield grade 1 and 2, %	20.6	6.6	25.3	29.0	2.92	< 0.01	< 0.01	0.81
Yield grade 3, %	60.1	68.6	63.1	57.5	3.45	< 0.01	0.72	0.04
Yield grade 4 and 5, %	19.3	24.9	11.6	13.6	2.44	< 0.01	< 0.01	< 0.01

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.6 Main effect of season of arrival on feedlot performance, health, and carcass traits for Angus steers, originating in the Central and South Central regions fed in a single Kansas feedlot from 1997-2007 (all weights included).

	Season of Arrival[1]					*P*-value		
Trait	Spr	Sum	F	W	SEM[2]	Season	Initial BW × Season	Spr + Sum vs. F + W
n	1,864	1,914	5,095	6,601				
Initial BW[3], kg	376	381	344	337	1.4	< 0.01	-	< 0.01
Final BW[3], kg	585	580	577	578	1.1	< 0.01	< 0.01	< 0.01
ADG[3], kg/d	1.67	1.68	1.56	1.72	0.008	< 0.01	< 0.01	< 0.01
d on feed[3]	143	136	151	132	0.6	< 0.01	< 0.01	< 0.01
Number of treatments[4]	0.13	0.35	0.20	0.21	0.026	< 0.01	0.03	0.13
HCW[3], kg	375	372	373	371	0.7	< 0.01	< 0.01	0.01
HCW ≥ 454 kg, %	0.8	0.3	0.2	0.4	0.17	1.00	1.00	0.99
USDA Quality grade[3,5]	2.70	2.80	2.73	2.72	0.014	< 0.01	< 0.01	0.02
Prime[3], %	3.4	1.7	2.0	2.0	0.42	0.35	0.21	0.44
Premium choice[3,6], %	18.1	21.9	17.7	20.2	1.09	< 0.01	< 0.01	0.58
Choice[3], %	64.3	76.8	70.2	68.5	1.25	< 0.01	< 0.01	0.04
Select[3], %	31.3	20.9	26.5	28.7	1.21	< 0.01	< 0.01	< 0.01
Ungraded[3], %	1.0	0.6	1.3	0.8	0.26	0.16	0.34	0.97
USDA Yield grade	2.81	2.92	2.90	2.84	0.017	< 0.01	< 0.01	0.76
Yield grade 1 and 2, %	28.5	20.9	25.5	27.2	1.16	< 0.01	< 0.01	0.03
Yield grade 3, %	60.6	64.9	58.2	60.5	1.33	< 0.01	< 0.01	0.01
Yield grade 4 and 5, %	10.9	14.1	16.3	12.4	0.90	< 0.01	< 0.01	0.19

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.7 Main effect of season of arrival on feedlot performance, health, and carcass traits for Angus steers, originating in the Central and South Central regions with arrival weight of 295-330 kg fed in a single Kansas feedlot from 1997-2007.

	Season of Arrival[1]					*P*-value	
Trait	Spr	Sum	F	W	SEM[2]	Season	Spr + Sum vs. F+ W
n	167	382	989	680			
Initial BW[3], kg	315	312	314	313	1.0	0.03	0.68
Final BW[3], kg	560	575	558	564	4.2	< 0.01	0.02
ADG[3], kg/d	1.74	1.69	1.51	1.71	0.029	< 0.01	< 0.01
d on feed[3]	143	156	166	148	2.1	< 0.01	< 0.01
Number of treatments[4]	0.27	0.39	0.26	0.27	0.095	0.36	0.36
HCW[3], kg	358	368	362	362	2.7	< 0.01	0.59
USDA Quality grade[3,5]	2.68	2.87	2.78	2.78	0.051	< 0.01	0.84
Premium choice[3,6], %	9.9	26.5	23.0	21.9	4.42	0.08	0.42
Choice[3], %	62.3	82.1	72.0	72.7	4.70	< 0.01	0.04
Select[3], %	31.6	15.2	24.1	24.6	4.51	< 0.01	0.03
USDA Yield grade	2.65	2.98	2.86	2.78	0.051	< 0.01	0.95
Yield grade 1 and 2, %	37.9	14.4	26.4	32.6	3.55	< 0.01	0.02
Yield grade 3, %	57.4	72.9	60.2	56.5	3.96	< 0.01	0.02
Yield grade 4 and 5, %	4.7	12.7	13.3	10.9	2.55	0.03	0.33

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3, 4, and 5 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.8 Main effect of season of arrival on feedlot performance, health, and carcass traits for Angus steers, originating in the Central and South Central regions with arrival weight of 331-375 kg fed in a single Kansas feedlot from 1997-2007.

	Season of Arrival[1]					*P*-value	
Trait	Spr	Sum	F	W	SEM[2]	Season	Spr + Sum vs. F + W
n	425	528	1,326	1,828			
Initial BW[3], kg	357	351	351	356	0.82	< 0.01	0.27
Final BW[3], kg	581	591	572	577	2.5	< 0.01	< 0.01
ADG[3], kg/d	1.72	1.70	1.59	1.75	0.018	< 0.01	< 0.01
d on feed[3]	133	141	141	128	1.1	< 0.01	< 0.01
Number of treatments[4]	0.17	0.37	0.17	0.15	0.045	< 0.01	< 0.01
HCW[3], kg	374	380	368	370	1.6	< 0.01	< 0.01
USDA Quality grade[3,5]	2.75	2.84	2.76	2.79	0.03	0.07	0.46
Premium choice[3,6], %	23.5	31.3	22.4	27.3	2.73	< 0.01	0.09
Choice[3], %	68.4	79.3	73.8	73.9	2.75	< 0.01	0.03
Select[3], %	26.3	17.6	23.2	23.2	2.64	< 0.01	< 0.01
USDA Yield grade	2.82	2.95	2.95	2.80	0.031	< 0.01	0.60
Yield grade 1 and 2, %	27.0	19.0	24.9	29.8	2.07	< 0.01	< 0.01
Yield grade 3, %	63.7	66.1	55.6	58.4	2.42	< 0.01	< 0.01
Yield grade 4 and 5, %	9.3	14.9	19.6	11.8	1.71	< 0.01	< 0.01

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.9 Main effect of season of arrival on feedlot performance, health, and carcass traits for Angus steers, originating in the Central and South Central regions with arrival weight of > 375 kg fed in a single Kansas feedlot from 1997-2007.

	Season of Arrival[1]					*P*-value	
Trait	Spr	Sum	F	W	SEM[2]	Season	Spr + Sum vs. F + W
n	1,081	559	1,389	3,465			
Initial BW[3], kg	421	414	414	415	1.8	< 0.01	0.06
Final BW[3], kg	616	598	600	600	2.2	< 0.01	< 0.01
ADG[3], kg/d	1.71	1.69	1.63	1.74	0.017	< 0.01	0.19
d on feed[3]	116	108	116	106	1.1	< 0.01	0.08
Number of treatments[4]	0.02	0.30	0.11	0.12	0.030	< 0.01	0.06
HCW[3], kg	396	383	387	385	1.4	< 0.01	< 0.01
USDA Quality grade[3,5]	2.87	2.80	2.81	2.78	0.027	< 0.01	0.03
Premium choice[3,6], %	29.9	25.8	27.0	24.1	2.51	0.13	0.19
Choice[3], %	74.8	76.2	77.1	73.7	2.49	0.03	0.21
Select[3], %	18.6	21.8	20.0	23.7	2.37	0.07	0.04
USDA Yield grade	2.83	2.83	2.92	2.86	0.027	< 0.01	< 0.01
Yield grade 1 and 2, %	28.7	29.1	24.4	25.6	1.84	0.03	< 0.01
Yield grade 3, %	59.5	57.5	59.0	62.2	2.13	0.09	0.04
Yield grade 4 and 5, %	11.8	13.4	16.6	12.1	1.46	< 0.01	0.49

[1] Region: SE: Alabama, Georgia, Mississippi, South Carolina, Tennessee, Virginia, and West Virginia; NC: Montana, Nebraska, and Wyoming; C: Colorado and Kansas; SC: New Mexico, Oklahoma, and Texas.
[2] SEM = largest standard error in the analysis.
[3] Only yield grade 3 cattle included in the analysis to eliminate bias caused by differences in fat endpoints.
[4] Includes all health treatments received per animal while at the feedlot.
[5] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[6] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.10 Effects of arrival weight on feedlot performance and carcass traits of Angus steers which were not treated for disease.

	Arrival weight (kg)						*P*-value	
Trait	< 295	295-330	330-375	375-409	> 409	SEM[1]	Lin	Quad
n	2,516	2,252	4,312	3,519	3,673			
Initial BW, kg	255	313	353	391	440	0.4	< 0.01	< 0.01
Final BW, kg	556	564	576	591	613	0.9	< 0.01	< 0.01
ADG, kg/d	1.51	1.63	1.70	1.73	1.69	0.006	< 0.01	< 0.01
d on feed	204	157	133	117	103	0.5	< 0.01	< 0.01
Number of treatments[2]	0.40	0.30	0.22	0.13	0.13	0.021	< 0.01	< 0.01
HCW, kg	359	363	370	380	394	0.6	< 0.01	< 0.01
HCW ≥ 454 kg, %	0.2	0.2	0.0	0.2	1.7	0.14	0.96	0.95
USDA Quality grade[3]	2.71	2.73	2.73	2.75	2.75	0.011	< 0.01	0.99
Prime, %	1.8	2.3	2.1	2.4	2.7	0.33	0.18	< 0.01
Premium choice[4], %	16.9	19.7	18.7	20.8	19.6	0.85	< 0.01	0.05
Choice, %	68.3	69.5	69.5	71.1	70.2	0.98	0.02	0.27
Select, %	29.1	27.0	27.4	25.9	26.2	0.94	< 0.01	0.12
Ungraded, %	0.9	1.3	1.1	0.6	0.8	0.20	0.18	0.39
USDA Yield grade	2.90	2.87	2.87	2.87	2.90	0.014	0.93	< 0.01
Yield grade 1 and 2, %	23.2	26.8	26.2	26.1	23.6	0.91	0.07	< 0.01
Yield grade 3, %	62.0	59.1	59.2	60.3	62.4	1.04	0.46	< 0.01
Yield grade 4 and 5, %	14.9	14.1	14.6	13.6	14.0	0.71	0.22	0.63

[1] SEM = largest standard error in the analysis.
[2] Includes all health treatments received per animal while at feedlot; Cattle treated for disease were included only for this calculation.
[3] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[4] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.11 Main effects of number of times treated for morbidity on feedlot performance and carcass traits for Angus steers arriving in the Fall and Winter from the Central and South Central regions fed in a single Kansas feedlot from 1997-2007. (All weights of cattle included.)

	Number of times treated[1]					*P*-value		
							Number of times treated	
Trait	0	1	2	≥ 3	SEM[2]	Initial BW × Number of times treated	Lin	Quad
n	10,700	333	204	360				
Initial BW, kg	362	322	331	338	1.5	-	< 0.01	< 0.01
Final BW, kg	577	586	564	557	3.1	< 0.01	< 0.01	< 0.01
ADG, kg/d	1.64	1.67	1.48	1.48	0.022	0.02	< 0.01	0.40
d on feed	142	149	150	145	1.9	< 0.01	0.03	< 0.01
HCW, kg	372	378	365	360	2.0	< 0.01	< 0.01	< 0.01
HCW ≥ 454 kg, %	0.4	0.5	0.4	0.1	0.42	1.00	0.97	0.98
USDA Quality grade[3]	2.72	2.70	2.58	2.56	0.039	0.50	< 0.01	0.91
Prime, %	2.1	2.2	0.8	0.7	1.10	1.00	0.96	0.97
Premium choice[4], %	18.6	13.0	11.5	12.4	3.00	0.81	< 0.01	< 0.01
Choice, %	69.0	65.5	58.3	57.1	3.50	0.94	< 0.01	0.03
Select, %	27.9	32.3	39.4	40.2	3.40	0.74	< 0.01	< 0.01
Ungraded, %	0.9	0.1	1.5	2.1	0.71	1.00	0.97	0.94
USDA Quality grade[5]	2.77	2.76	2.67	2.67	0.045	0.49	< 0.01	0.92
Prime[5], %	2.2	2.9	1.1	1.4	1.40	1.00	0.96	0.98
Premium choice[5], %	24.4	16.5	16.2	17.9	4.05	0.60	0.02	< 0.01
Choice[5], %	73.1	70.7	64.7	64.0	4.17	0.90	0.01	0.19
Select[5], %	24.2	26.4	34.2	34.6	4.02	0.76	< 0.01	0.14
Ungraded[5], %	0.5	0.1	0.0	0.0	0.61	1.00	0.93	0.93
USDA Yield grade	2.88	2.91	2.72	2.68	0.037	0.87	< 0.01	0.33
Yield grade 1 and 2, %	25.8	25.0	32.0	37.3	3.24	0.99	< 0.01	0.79
Yield grade 3, %	59.7	59.5	62.6	53.6	3.74	1.00	0.89	0.33
Yield grade 4 and 5, %	14.4	15.5	5.4	9.2	2.55	0.67	0.93	0.94

[1] Treated: Includes all health treatments received while at feedlot.
[2] SEM = largest standard error in the analysis.
[3] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[4] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).
5 For only those cattle marketed at Yield grade 3**.**

Table 2.12 Main effects of number of times treated for morbidity on feedlot performance and carcass traits for 295-329 kg Angus steers arriving in the Fall and Winter from the Central and South Central regions fed in a single Kansas feedlot from 1997-2007.

	Number of times treated[1]					*P*-value	
Trait	0	1	2	≥ 3	SEM[2]	Lin	Quad
n	1,513	34	33	89			
Initial BW, kg	314	309	312	313	1.7	0.94	0.02
Final BW, kg	556	556	529	532	7.3	< 0.01	0.73
ADG, kg/d	1.60	1.59	1.43	1.43	0.052	< 0.01	0.79
d on feed	154	158	159	158	4.0	0.19	0.35
HCW, kg	359	359	343	345	4.6	< 0.01	0.85

[1] Treated: Includes all health treatments received while at feedlot.
[2] SEM = largest standard error in the analysis.
[3] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[4] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).
5 For only those cattle marketed at Yield grade 3.

Table 2.13 Main effects of number of times treated for morbidity on feedlot performance and carcass traits for 330-375 kg Angus steers arriving in the Fall and Winter from the Central and South Central regions fed in a single Kansas feedlot from 1997-2007.

	Number of times treated[1]					*P*-value	
Trait	0	1	2	≥ 3	SEM[2]	Lin	Quad
n	2,938	78	53	85			
Initial BW, kg	354	354	349	352	1.8	0.10	0.21
Final BW, kg	575	573	563	559	5.5	< 0.01	0.71
ADG, kg/d	1.70	1.70	1.60	1.53	0.041	< 0.01	0.23
d on feed	132	130	136	137	2.7	< 0.01	0.57
HCW, kg	369	369	363	360	3.5	< 0.01	0.66

[1] Treated: Includes all health treatments received while at feedlot.
[2] SEM = largest standard error in the analysis.
[3] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[4] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).
5 For only those cattle marketed at Yield grade 3.

Table 2.14 Main effects of number of times treated for morbidity on feedlot performance and carcass traits for > 375 kg Angus steers arriving in the Fall and Winter from the Central and South Central regions fed in a single Kansas feedlot from 1997-2007.

	Number of times treated[1]					*P*-value	
Trait	0	1	2	≥ 3	SEM[2]	Lin	Quad
n	4,674	100	48	91			
Initial BW, kg	415	411	415	412	4.3	0.73	0.76
Final BW, kg	600	606	584	585	5.5	< 0.01	0.55
ADG, kg/d	1.70	1.73	1.46	1.54	0.043	< 0.01	0.40
d on feed	109	114	117	114	2.5	< 0.01	0.04
HCW, kg	386	391	376	376	3.6	< 0.01	0.25

[1] Treated: Includes all health treatments received while at feedlot.
[2] SEM = largest standard error in the analysis.
[3] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[4] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).
5 For only those cattle marketed at Yield grade 3.

Table 2.15 Main and interactive effects of quality grade on feedlot performance and carcass traits for Angus steers never treated for disease fed in a single Kansas feedlot from 1997-2007.

	Quality grade					*P*-value	
Trait	Prime	Choice	Select	Ungraded	SEM[1]	Lin	Quad
n	394	11,401	4,336	141			
Initial BW, kg	374	362	359	355	5.3	< 0.01	0.22
Final BW, kg	586	585	578	563	3.8	< 0.01	< 0.01
ADG, kg/d	1.61	1.68	1.63	1.50	0.025	< 0.01	< 0.01
d on feed	133	136	138	141	3.4	0.05	0.87
Number of treatments[23]	0.05	0.06	0.09	0.11	0.024	0.05	0.26
HCW, kg	377	376	372	363	2.4	< 0.01	< 0.01
HCW ≥ 454 kg, %	0.5	0.4	0.6	0.2	0.56	0.98	0.98
USDA Yield grade	2.99	2.94	2.74	2.31	0.053	< 0.01	< 0.01
Yield grade 1 and 2, %	18.9	20.9	35.7	59.4	3.53	< 0.01	< 0.01
Yield grade 3, %	63.9	64.0	52.4	32.5	4.08	< 0.01	< 0.01
Yield grade 4 and 5, %	17.1	15.1	11.9	8.1	2.80	< 0.01	0.03

[1] SEM = largest standard error in the analysis.
[2] Includes all health treatments received while at feedlot.
[3] Includes all steers in the complete dataset. Animals which had been treated for disease were removed from analysis of all other variables.

Table 2.16 Main and interactive effects of quality grade on feedlot performance and carcass traits for Angus steers from the Central and South Central Regions Arriving in the Fall and Winter never treated for respiratory disease marketed at Yield Grade 3, 4, or 5 fed in a single Kansas feedlot from 1997-2007.

	Quality grade					*P*-value	
Trait	Prime	Choice	Select	Ungraded	SEM[1]	Lin	Quad
n	156	5,972	1,820	32			
Initial BW, kg	364	366	362	368	10.4	0.84	0.70
Final BW, kg	582	586	581	569	7.6	0.07	0.04
ADG, kg/d	1.65	1.69	1.64	1.49	0.051	< 0.01	< 0.01
d on feed	133	134	138	136	6.9	0.60	0.78
HCW, kg	375	377	375	368	4.8	0.12	0.09
HCW ≥ 454 kg, %	0.0	0.4	0.8	0.3	1.10	0.99	0.99

[1] SEM = largest standard error in the analysis.

Table 2.17 Main and interactive effects of yield grade on feedlot performance and carcass traits for Angus steers never treated for respiratory disease fed in a single Kansas feedlot from 1997-2007.

	Yield grade				*P*-value	
Trait	1+2	3	4+5	SEM[1]	Lin	Quad
n	4,145	9,912	2,215			
Initial BW, kg	359	360	358	1.4	0.95	0.29
Final BW, kg	572	584	599	0.98	< 0.01	0.21
ADG, kg/d	1.62	1.67	1.72	0.006	< 0.01	0.72
d on feed	133	136	143	0.89	< 0.01	0.05
Number of treatments[23]	0.34	0.19	0.13	0.021	< 0.01	< 0.01
HCW, kg	368	376	385	0.62	< 0.01	0.18
HCW ≥ 454 kg, %	0.4	0.4	1.0	0.14	0.06	0.91
USDA Quality grade[4]	2.59	2.78	2.81	0.011	< 0.01	< 0.01
Prime, %	1.7	2.4	2.9	0.33	< 0.01	0.04
Premium Choice[5], %	14.9	25.2	1.3	0.85	< 0.01	< 0.01
Choice, %	57.6	73.7	75.3	0.99	< 0.01	< 0.01
Select, %	38.7	23.4	21.5	0.95	< 0.01	< 0.01
Ungraded, %	2.1	0.5	0.4	0.20	< 0.01	< 0.01
Yield grade	1.95	3.00	4.04	0.003	< 0.01	0.05

[1] SEM = largest standard error in the analysis.
[2] Includes all health treatments received while at feedlot.
[3] Includes all steers in the complete dataset. Animals which had been treated for disease were removed from analysis of all other variables.
[4] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[5] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.18 Effects of average daily gain on feedlot performance and carcass traits of Angus steers which were not treated for disease fed in a single Kansas feedlot from 1997-2007 (all weights included).

	ADG (kg)					*P*-value		
							ADG	
Trait	< 1.36	1.36-1.55	1.56-1.81	> 1.81	SEM[1]	Initial BW × ADG	Lin	Quad
n	2,736	3,236	5,280	5,020				
Initial BW, kg	342	344	362	378	0.4	-	< 0.01	< 0.01
Final BW, kg	532	566	584	609	0.7	< 0.01	< 0.01	< 0.01
ADG, kg/d	1.19	1.47	1.68	1.99	0.003	< 0.01	< 0.01	< 0.01
d on feed	154	149	139	129	0.5	< 0.01	< 0.01	< 0.01
HCW, kg	345	365	346	390	0.5	< 0.01	< 0.01	< 0.01
HCW ≥ 454 kg, %	0.0	0.1	0.5	0.9	0.13	1.00	0.96	0.98
USDA Quality grade[2]	2.66	2.72	2.75	2.78	0.010	< 0.01	< 0.01	0.06
Prime, %	3.2	2.8	1.9	2.2	0.31	0.01	0.02	0.15
Premium choice[3], %	15.6	18.0	20.3	22.0	0.81	0.01	< 0.01	< 0.01
Choice, %	61.2	67.6	72.0	73.7	0.93	< 0.01	< 0.01	< 0.01
Select, %	34.0	28.6	25.2	23.5	0.90	< 0.01	< 0.01	< 0.01
Ungraded, %	1.6	1.1	0.9	0.6	0.19	0.46	< 0.01	0.05
USDA Yield grade	2.75	2.87	2.90	2.93	0.013	0.01	< 0.01	< 0.01
Yield grade 1 and 2, %	32.8	25.3	23.6	22.8	0.86	0.03	< 0.01	< 0.01
Yield grade 3, %	57.4	61.1	62.4	60.8	0.99	< 0.01	< 0.01	< 0.01
Yield grade 4 and 5, %	9.8	13.6	14.0	16.4	0.68	< 0.01	< 0.01	< 0.01

[1] SEM = largest standard error in the analysis.
[2] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[3] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.19 Effects of average daily gain on feedlot performance and carcass traits of Angus steers with initial BW between 295 to 330 kg which were not treated for disease fed in a single Kansas feedlot from 1997-2007.

	ADG (kg)					*P*-value	
Trait	< 1.36	1.36-1.55	1.56-1.81	> 1.81	SEM[1]	Lin	Quad
n	382	323	521	383			
Initial BW, kg	313	314	315	317	0.62	< 0.01	0.40
Final BW, kg	510	548	563	592	1.9	< 0.01	< 0.01
ADG, kg/d	1.17	1.46	1.67	1.97	0.008	< 0.01	0.17
d on feed	171	161	149	140	1.2	< 0.01	0.93
HCW, kg	333	355	362	378	1.3	< 0.01	< 0.01
USDA Quality grade[2]	2.54	2.76	2.78	2.77	0.032	< 0.01	< 0.01
Prime, %	2.1	4.7	3.3	3.5	0.94	0.45	0.15
Premium choice[3], %	11.8	20.5	24.0	24.5	2.48	< 0.01	< 0.01
Choice, %	50.5	67.5	72.4	70.3	2.85	< 0.01	< 0.01
Select, %	46.3	26.5	22.7	25.3	2.74	< 0.01	< 0.01
USDA Yield grade	2.71	2.83	2.85	2.93	0.40	< 0.01	0.57
Yield grade 1 and 2, %	33.1	27.3	27.3	25.8	2.70	< 0.01	< 0.01
Yield grade 3, %	60.8	62.2	60.4	55.4	3.09	0.59	0.09
Yield grade 4 and 5, %	6.2	10.6	12.3	18.8	2.07	< 0.01	< 0.01

[1] SEM = largest standard error in the analysis.
[2] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[3] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.20 Effects of average daily gain on feedlot performance and carcass traits of Angus steers with initial BW between 330 to 375 kg which were not treated for disease fed in a single Kansas feedlot from 1997-2007.

	ADG (kg)					*P*-value	
Trait	< 1.36	1.36-1.55	1.56-1.81	> 1.81	SEM[1]	Lin	Quad
n	412	504	961	1061			
Initial BW, kg	353	352	354	355	0.7	< 0.01	0.09
Final BW, kg	521	554	574	605	1.5	< 0.01	0.17
ADG, kg/d	1.19	1.47	1.69	2.01	0.007	< 0.01	< 0.01
d on feed	144	138	131	125	0.9	< 0.01	0.60
HCW, kg	338	357	369	387	1.0	< 0.01	0.20
USDA Quality grade[2]	2.61	2.66	2.77	2.78	0.026	< 0.01	0.31
Prime, %	4.1	2.1	2.1	1.9	0.75	< 0.01	0.11
Premium choice[3], %	11.4	18.3	21.4	19.1	2.01	< 0.01	< 0.01
Choice, %	54.5	63.9	72.9	74.1	2.33	< 0.01	0.03
Select, %	39.6	31.9	24.7	23.6	2.26	< 0.01	0.06
USDA Yield grade	2.75	2.87	2.85	2.95	0.033	< 0.01	0.59
Yield grade 1 and 2, %	33.1	24.8	28.0	24.6	2.14	< 0.01	0.14
Yield grade 3, %	57.7	61.9	58.2	55.2	2.54	0.24	0.07
Yield grade 4 and 5, %	9.2	13.3	13.8	20.2	1.83	< 0.01	0.44

[1] SEM = largest standard error in the analysis.
[2] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[3] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.21 Effects of average daily gain on feedlot performance and carcass traits of Angus steers with initial BW between > 375 kg which were not treated for disease fed in a single Kansas feedlot from 1997-2007.

	ADG (kg)					*P*-value	
Trait	< 1.36	1.36-1.55	1.56-1.81	> 1.81	SEM[1]	Lin	Quad
n	533	693	1,201	1,542			
Initial BW, kg	408	407	406	405	0.91	< 0.01	0.99
Final BW, kg	547	576	595	621	1.3	< 0.01	0.18
ADG, kg/d	1.20	1.47	1.69	2.02	0.006	< 0.01	< 0.01
d on feed	117	115	112	107	0.7	< 0.01	< 0.01
HCW, kg	353	372	383	398	0.9	< 0.01	< 0.01
USDA Quality grade[2]	2.75	2.76	2.74	2.76	0.022	0.94	0.82
Prime, %	2.0	3.5	2.4	1.2	0.64	0.16	< 0.01
Premium choice[3], %	21.4	21.2	19.5	19.7	1.82	0.32	0.90
Choice, %	72.7	70.3	70.0	73.7	2.05	0.76	0.04
Select, %	23.3	25.4	26.9	24.8	1.99	0.42	0.17
USDA Yield grade	2.77	2.82	2.90	2.93	0.024	< 0.01	0.54
Yield grade 1 and 2, %	32.0	28.4	23.0	23.3	1.89	< 0.01	0.17
Yield grade 3, %	57.5	60.0	63.4	61.2	2.22	0.09	0.16
Yield grade 4 and 5, %	10.5	11.7	13.7	15.6	1.56	< 0.01	0.75

[1] SEM = largest standard error in the analysis.
[2] Quality grade: 4.0 = Prime; 3.0 = Choice; 2.0 = Select; 1.0 = Ungraded.
[3] Premium Choice: Qualified for Certified Angus Beef or Sterling Silver (≥ Modest^0 marbling; medium or fine marbling texture; ≤ 30 months of age; 64.5 – 103.2 cm^2 ribeye area; < 455 kg carcass weight; < 2.54 cm fat thickness; superior muscling; practically free of capillary ruptures; no dark cutters; no neck hump exceeding 5.1 cm).

Table 2.22 Correlation coefficients (Pearson) of various traits in Angus steers fed in a single feedlot between 1997 and 2007 (P < 0.01).

Item	Initial BW, kg	ADG, kg	Final BW, kg	HCW, kg	Number of treatments[1]	Yield grade
ADG, kg	0.185					
Final BW, kg	0.425	0.616				
HCW, kg	0.405	0.562	0.986			
Number of treatments	-0.104	-0.152	-0.146	-0.140		
Yield grade	0.021	0.131	0.240	0.238	-0.073	
Quality grade[2]	0.036	0.074	0.104	0.097	-0.069	0.167
Quality grade[3]	0.038	0.062	0.097	0.089	-0.070	0.192

[1] Includes all health treatments received while at feedlot.
[2] Prime = 4, Choice = 3, Select = 2, Ungraded = 1.
[3] Yield grade 4 and 5 removed; Prime = 5, Premium Choice = 4, Choice = 3, Select = 2, Ungraded =1.