FORAGE QUALITY, ANIMAL PERFORMANCE, AND CARCASS TRAITS OF STEERS FINISHED ON WINTER ANNUAL RYEGRASS (*Lolium multiflorum* Lam.) PASTURE WITH VARYING LEVELS OF CORN SUPPLEMENTATION

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VITA

Sean D. Roberts, the son of David and Jennifer Roberts, was born on December 5, 1978 in Carthage, IL. Sean grew up on the family cattle farm in Plymouth, IL. In August, 1998 he moved with his family to Ft. Payne, AL. Sean enrolled at Auburn University and graduated in December, 2001, Magna Cum Laude, with a B.S. degree in Agricultural Economics. Following graduation e went to work for Circle G ranch in Hampton, GA for one year before returning to Auburn University to pursue a Masters degree in Animal Science with an emphasis on Meat Science and Muscle Biology. Sean plans to graduate in December, 2005.

THESIS ABSTRACT

FORAGE QUALITY, ANIMAL PERFORMANCE, AND CARCASS TRAITS OF STEERS FINISHED ON WINTER ANNUAL RYEGRASS (*Lolium multiflorum* Lam.) PASTURE WITH VARYING LEVELS OF CORN SUPPLEMENTATION

Sean David Roberts

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Crossbred steers (n=72) from E.V. Smith Beef Research Unit resident herd were selected to study forage based finishing systems using winter annual ryegrass (*Lolium multiflorum* Lam.) with varying levels of supplementation. In December 2003, cattle were allotted to one of six treatments with diets consisting of ryegrass pasture (1 ha) with whole shell corn supplemented at 0.0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), and 2.0% (2.0) of bodyweight, or ad-libitum mixed ration grain diet in drylot (GRAIN). Steers were randomly placed in pens of four with pen serving as the experimental unit. Cattle were harvested by pen when average pen backfat thickness reached approximately

6.35 mm. Forage samples and disk meter height were taken from ryegrass paddocks on a monthly basis to determine forage quality and mass. Following harvest of cattle, live animal performance, carcass traits, and proximate analysis, WBS, and sensory characteristics from the longissimus muscle (LM) of the rib section were analyzed. Finishing diet had no significant effect ($P > 0.05$) on animal performance as indicated by similar ADG and days on feed among diets. GRAIN and 2.0 treatments had a higher ($P < 0.05$) dressing percentage than 0.0 and 0.5 steers. Yield grade was lower ($P < 0.05$) for 0.0, 0.5 and 1.0 steers than those finished in the GRAIN group. Marbling scores and lean maturity were similar ($P > 0.05$) among treatments. WBS and sensory scores were unaffected ($P > 0.05$) by diet with the exception of lower ($P < 0.05$) sustained tenderness scores for 1.0 treatment. Forage quality was similar ($P > 0.05$) across pasture treatments for neutral detergent fiber, acid detergent fiber, and protein, while ash was higher ($P < 0.05$) in the 0.0 paddocks. In April, an incremental increase ($P < 0.05$) in dry matter mass (3312 kg ha^{-1} to 6973 kg ha^{-1}) within paddocks was found with each increase in the amount of supplemental grain. Supplementation of finishing steers on annual ryegrass had little effect on animal performance, carcass traits, and palatability attributes. Forage mass was increased by adding supplemental corn to the diet.

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CHAPTER I

INTRODUCTION

Finishing beef in a forage-based system has been discussed as an alternative to grain finishing in a feedlot. Many times during the last fifty years this subject has come up, but to date forage-finishing of beef has not become a wide spread method in the United States to finish beef. Early research found quality problems associated with forage-finished beef. Forage-fed slaughter cattle have been less acceptable to packers due to lower dressing percentage, higher cooler shrink, and lower quality grade (Brown, 1954). Craig et al. (1959) reported that forage-fed beef might be less acceptable to consumers because of differences in color of either the lean or the fat. Along with poor quality grade, researchers have found palatability issues, primarily related to flavor, when comparing animals finished on an all forage diet and those finished on a high concentrate diet (Bowling et al., 1977, 1978; Melton et al., 1982, 1990; Larick and Turner, 1987, 1990). Research shows that forage-finished cattle take longer to reach market weight and have lower average daily gains than grain-fed cattle (Bidner et al., 1986; Bennett et al., 1995). Grass-fed beef has been shown to be more susceptible to oxidation than grain-fed beef causing shorter shelf life and flavor stability (Reverte et al., 2003; Larick et al., 1987). Greibenow et al. (1997) points out that there is conflicting research related to most of the problems associated with forage-finished beef. This indicates that there may

be methods of producing forage-finished beef that results in acceptable consumer satisfaction, animal performance, and/or carcass characteristics.

Researchers have investigated all forage-finished or increased forage use in production of slaughter cattle for a number of reasons throughout the years. Bowling et al., (1977) reported that interest in forage-finished beef cattle in the United States usually coincides with periods of food grain shortages. Concerns over availability and rising prices of cereal grains used in feedlot cattle production fueled the early forage-finished beef research (Oltjen et al., 1971; Bowling et al., 1977, 1978; Cross and Dinius, 1978; Clanton, 1977; Smith et al., 1977). In the early 1980's, consumers became increasingly concerned with excessive fat in red meats (Crouse et al., 1984). As a result of consumer demands, forage-finishing and decreased grain consumption in beef production was investigated for its ability to produce a leaner product (Crouse et al., 1984; Crouse and Seideman, 1984; Bidner et al., 1986; McMillin et al., 1990, Schaake et al., 1993; Duckett et al., 1993). Though a high-energy diet consisting primarily of cereal grains is used to finish most beef cattle in the United States, cattle cannot compete with monogastric animals in conversion of such a diet to meat (Griebenow et al., 1997). It seems as though the beef industry's strength lies in its ability to convert forages into a high-protein product.

Investigators have explored the possibilities of implementing a forage-finishing system to better utilize available low and high quality forages. For this reason, Allen et al., (1996); Bennett et al., (1995); Schaake et al., (1993); McMillin et al., (1990); and Binder et al., (1981) have investigated forage-finishing systems in the southeastern United States. The southeastern United States has traditionally consisted of cow-calf and

stocker operations, with very little finishing of beef for consumption. The region has climates and soils that are well suited to forage production and can support nearly year-round grazing. This leads one to believe that there are possibilities to develop forage-finishing systems in the region.

Most recent interest in forage-finished beef has been spurred by research that indicates that including forages in the animal's diet produces meat that provides a number of health benefits to the consumer when compared to a grain diet. Along with being leaner, Mitchell et al., (1991) found that forage-fed beef had a higher proportion of *n* - 3 polyunsaturated fatty acids (in particular 18:3*n* – 3) than grain-fed beef. A more acceptable ratio of *n* – 6 to *n* – 3 fatty acids has been found in grass-fed animals in comparison to concentrate-fed animals (Elmore et al., 2004). Beef produced on forage has been shown to contain more conjugated linoleic acid (CLA) when compared with beef from grain-supplemented cattle (Shantha et al., 1997). Yang et al., (2002) found that pasture-fed beef was higher in polyunsaturated fatty acids (PUFA) while being lower in oleic acid than grain-fed cattle. This indicated that grass-fed cattle have a higher ratio of polyunsaturated fatty acids to saturated fatty acids (P:S). Wood et al., (2002) reported that meats with a low P:S ratio could be associated with an imbalanced fatty acid intake of today's consumer.

The health benefits associated with forage-finished beef along with increased consumer demand for 'organic' and 'all-natural' products have led researchers and producers to reevaluate forage-finishing systems for beef. It is believed that a niche market can be formed in which forage-finished beef can demand a higher price than grain-finished animals (Nader et al., 1998). Umberger et al. (2002) found that 23% of the

consumers preferred Argentine grass-fed beef over domestic grain-fed beef and were willing to pay a premium of $1.36 more per pound for the grass-fed beef. A consumer study in the southeastern region of the United States found that 34% of consumers preferred the taste of grass-fed beef to that of grain-fed (Cox, 2004).

The use of supplement (grain) in a forage finishing system may allow cattle producers to utilize available forages while retaining interest in cattle for local markets. The purpose of this study was to analyze cattle performance, carcass attributes, palatability attributes, and forage quality and herbage availability between treatments of cattle receiving various levels of concentrate supplement. Cattle finished on an all forage diet have not performed well when compared to those finished on a high-concentrate diet in a feedlot. The hypothesis is that addition of corn to high quality forage will improve animal performance and carcass quality.

CHAPTER II

REVIEW OF LITERATURE

Performance

Cattle performance is important for a number of reasons. Cattle grown rapidly prior to slaughter have been shown to produce more tender meat than slower growing counterparts (Aberle et al.,1981). This is attributed to increased protein turnover in rapidly growing cattle resulting in higher concentrations of proteolytic enzymes in the carcass tissues at harvest (Shackelford et al., 1994). Perry et al. (2002) showed a curvilinear relationship between finishing growth rate and palatability, which appears to plateau at a growth rate of approximately 1.2 kg/day. One problem with forages is that most forage systems do not provide the proper combination of protein and energy to allow growing cattle to gain weight at a rate that they can lay down excess fat.

It is well documented that steers finished on all forage diets have lower daily gains than contemporaries finished on a high-energy grain diet. Bowling et al. (1978) reported that steers fed grain in a feedlot reached slaughter weight (518 Kg) and grade 100 to 230 d sooner than those finished on forage systems. Bidner et al., (1981) found that it took an additional 160 d for steers fed forage to reach a slaughter weight of 476 kg compared with the average of three grain groups. In the same study, days to slaughter was decreased 165 d by adding 1% body weight of grain in addition to ryegrass and

bermudagrass pasture in comparison to pasture raised steers with no supplemental grain. This indicates that addition of grain to a pasture finishing system can significantly increase animal daily gains. O'Sullivan et al. (2003) studied the addition of concentrate to a forage diet in comparison to an all forage diet and ad-libitum concentrate diet in feedlot. Cattle on an all forage diet had daily gains that were significantly lower than cattle in five treatments receiving concentrate at various levels. In this study, there was no significant difference between daily gains for high herbage allowance and 2.5 kg concentrate (HHLC) steers and high herbage allowance and 5 kg concentrate (HHHC) steers. Daily gains for steers finished on a concentrate ad-libitum + 1 kg straw (CON) diet were not significantly higher than HHHC steers but gains were higher than HHLC steers. This study showed that average daily gain increases with addition of concentrate in the finishing diet.

Cattle Production

In a study conducted in Louisiana, McMillin et al. (1990) found that location of production of forage-finished cattle, although confounded with breed type and climate, had less effect on carcass traits than did season of production. Cattle finished on forages in the summer had carcasses with lower fat thickness measurements and quality grades than cattle finished on winter forages. In the same study, Bagley et al. (1988) reported that differences in animal weight gains were greatest when comparing silage-finished with forage-finished animals terminated in September and November, primarily due to poor animal performance for forage-finished cattle in the late summer months.

It is clear that the plane of nutrition is an important factor on carcass quality. In a study by Miller et al. (1981), steers finished on native Wyoming range were slaughtered

at 29 mo of age with 250 kg carcasses that graded USDA Standard while their contemporaries were placed in a feedlot for 120 d and slaughtered at 22 mo of age with 300 kg carcass that graded USDA Choice. Forage selection for the finishing stage in a forage-finishing system will be critical to achieve acceptable average daily gains in order to deposit fat. In a case study by Nader et al. (1998), a grass-fed beef producer reports that 114 kg of gain in the finishing stage is necessary for an economical and quality product. They also reported that added supplement is needed when forages cannot result in sufficient gain. By using cattle with good forage conversion rates and supplementing when needed, this producer was able to achieve 60% choice grade with minimal amount of external fat.

A primary issue of grass-fed beef is cattle production and performance during times of low-quality forages. Bodine and Purvis (2003) reported that nutrient deficiencies occur during dormant seasons and that supplementation is required for cattle to gain weight. Protein is considered the primary limiting nutrient, though, increased forage intake with protein supplementation might not result in adequate increases in energy intake for animal performance to achieve a desired rate of gain (Bowman and Sanson, 1996). Corn (high-starch, low-protein) grain supplemented to cattle consuming low-quality forages resulted in decreases in forage intake and digestibility (Horn and McCullum, 1987; Bowman and Sanson, 1996). Cattle grazing dormant pasture had greatest response in animal performance occurring when grain supplements were balanced for total diet degradable intake protein in relation to total diet TDN (Bodine and Purvis, 2003).

Supplementation

Supplementing grain to grazing cattle has been shown to be a practical method of shortening the finishing period while continuing to make use of the forage resource (Allen et al., 1996). Animal performance on forage diets is usually limited by energy intake, and rate of gain is generally increased by an energy supplement (Bidner et al., 1986). Goetsch et al. (1991) found that yearling steers grazing annual spring forages with 0.5% ground corn supplemented to them had greater average daily gains than those receiving no supplementation. Efficiency of energy utilization from supplementing corn on forages has shown to increase as forage quality declines (McMillin et al. 1990).

In a study of year-round forage-finishing systems, greater supplemental grain was fed to forage groups finished in September, November, and January to increase animal performance than for March-, May-, and July-finished groups (McMillin et al., 1990). The reason for this was that cool-season annual pastures of ryegrass and clover were primarily used for forage-finished groups harvested in March, May, and July, and very little supplemental grain was required to sustain adequate weight gains.

Forage-finishing in Southeast United States

The southern region of the U.S. has been described as an ideal area for forage production and grazing systems due to a mild climate and well distributed rainfall patterns (Allen et al., 1996). Because of these reasons, the area can produce forages almost year round (Bagley and Feazel, 1987). In a study of year-round forage-finishing systems, Bagley et al. (1988) reported that a wide variety of winter and summer annual and perennial forages could be utilized for forage-finishing of cattle in the southeastern U.S. Cool season annuals including, rye-ryegrass, wheat-ryegrass, cereal grain-ryegrass-

clover, and ryegrass-clover were utilized 29% of the time. Summer perennials were commonly used and included hybrid bermudagrass (Coastal, Alicia, Brazos), common bermundagrass, and bahiagrass. Grass-clover mixtures consisting of primarily bermudagrass and either white clover or arrowleaf clover were utilized 15% of the time. Summer annuals utilized included sorgham-sudangrass, millet, alycelover, and cowpeas.

Bermudagrass is the most widely grown warm-season perennial grass in the southeastern U.S. Forage quality of bermudagrass has been reported to decline in the middle to late grazing season (Utley et al., 1981; Aiken and Brown, 1996). Reductions in ADG on bermudagrass are attributed to higher energy requirements for maintenance as body weights increase over the grazing season and to lower forage quality in the late season (Hill et al., 2001). Aiken (2002) found that supplementation with ground corn at rates of 0.45 to 1.35 kg/steer a day can cost-effectively enhance weight gain of yearling steers grazing bermudagrass in the late season. This study found that supplementation of greater than 1.35 kg/steer a day had little effect on ADG and thus there were little economic incentives to feed above this point.

Cool-season annual forages have been shown to increase rates of performance and lower costs of gain for grazing steers in comparison with other forages (Bagley et al., 1988). A number of studies have shown that annual ryegrass can be utilized in the spring months to increase weight gains for stocker and finishing cattle (Bransby et al., 1997). Annual ryegrass is a high quality forage that requires increased labor, equipment, seed, and input in comparison to perennial forages (Allen et al., 2000). While forage quality is high in the early spring months, quality declines as plant matures in later months. In a study of six annual ryegrass cultivars, Redfearn et al. (2002) reported that crude protein

concentration differed significantly among harvest years with general decrease from 260 to 120 g CP kg^{-1} as the growing season progressed. Declines in crude protein occurred from April through the end of the growing season. It is suggested that the use of late-maturing cultivars such as Marshall and Rio would allow producers to extend the production of high-quality forage into late-spring (Redfearn et al., 2002). Forage mass of annual ryegrass has been reported in studies comparing various cultivars, stocking rates, and grazing method (Redfearn et al., 2002; Syfrett, 2003; Hafley, 1996). Redfearn et al. (2002) reported that 40% of the total forage production from the annual ryegrass cultivars occurred as early-season (December-February) growth with the remaining 60% occurring in late-season (March-May) growth. Approximately 30% of the total production occurred during April alone. While annual ryegrass does not present a year-round solution for production of forage-finished beef, it does present opportunities to finish cattle with adequate weight gain.

Forage mass determination

A rapid, reliable, and nondestructive technique for estimating forage mass is important to evaluate forage availability in grazing studies and establish grazing management decisions (Gonzalez et al., 1990). Forage mass has been shown to be highly correlated to livestock performance (Guerreo et al., 1984; Bransby et al., 1997). Herbage mass is often estimated by harvesting small, hand-clipped quadrants. The time required makes it difficult to obtain adequate sample numbers. Consequently, a mathematical relationship between hand-clipped estimates of forage mass were developed and these nondestructive techniques (double sampling) have been utilized. Gonzalez et al. (1990) studied the relationship between forage mass and three commonly utilized nondestructive

measurement techniques in bermudagrass plots and pastures. The three methods included estimated plant height measurements using a meter stick (Whitney, 1974), settled disk meter height (Bransby et al., 1977), and capacitance meters (Greathead et al., 1987). The double sampling methods studied all allowed for sufficient determination of forage mass. Use of disk meter and capacitance meter were more accurate for predicting forage mass in pastures, while plant height was more efficient estimator of forage mass in small plots.

Carcass traits

Research shows that finishing diet affects carcass traits in slaughter cattle. Cattle finished on higher energy diets have been shown to have larger hot carcass weights, higher quality grades, increased fat levels, and decreased cutability than carcasses of cattle finished on lower energy diets when finishing period lengths, cattle biological types, and age at slaughter were similar between dietary regiments (McMillin et al., 1990; Mandell et al., 1997; Crouse and Seideman, 1984). When forage-fed and grain-fed animals were harvested at similar weights forage-finished carcasses had less subcutaneous fat and lower marbling scores (Bidner et al., 1986, 1981; Dinius and Cross, 1978). Schaake et al. (1993) found that as the time period increased for cattle placed in feedlot, following a forage diet, subcutaneous fat, marbling scores, and yield grade increased.

Researchers have found larger longissimus muscle area in grain-finished cattle when compared to forage-finished cattle, which coincided with higher hot carcass weights (HCW) in the grain-finished cattle. Differences in longissimus muscle area between forage- and grain-finished cattle appear to be primarily due to differences in HCW. Ribeye area is similar in forage- and grain-finished cattle slaughtered at similar

weights (Mandell et al., 1998; Bidner et al., 1986). Bagley et al (1988) found forage-fed beef animals tended to have a greater proportion of ribeye area than did corn silage-finished animals (13.9 vs. 13.0 cm^2 per 50 kg of carcass weight).

Marbling is the term given to intramuscular fat deposited between muscle bundles. Increased marbling is often associated with improved tenderness, juiciness, and flavor (Crouse and Smith, 1978; Harrison et al., 1978; May et al., 1992). Some studies have found that the relationship between marbling and palatability characteristics to be weak and sometimes non-existent (Bowling et al., 1977, 1978; Reagan et al., 1981; Miller et al., 1987). May et al., (1992) found that marbling is positively associated with carcass weight ($r = 0.80$) and subcutaneous fat thickness ($r = 0.79$). Griebenow et al. (1997) concluded that research indicates forage-finished cattle tend to have less intramuscular fat than grain-fed cattle due to lower carcass weights and subcutaneous fat. When forage-finished and grain-finished cattle were slaughtered at similar fat cover, no differences were found in marbling scores or chemically measured intramuscular fat (Muir et al., 1998b; Mandell et al., 1997; Young and Kauffman, 1978).

It is possible that we can improve marbling in forage-finished beef by selecting cattle of certain biological type. Marshall (1994) indicated that, generally, smaller-framed breeds of cattle tend to have carcasses with higher degrees of marbling on an age-constant bases. This was backed up by Camfield et al. (1999), who found that marbling increased in pasture-raised steers as frame score decreased and cattle matured earlier. In this study, marbling scores (400 = slight) for small framed-early maturing and intermediate framed-early maturing steers (496.8 and 484.6, respectively) were significantly higher than marbling scores for intermediate framed-intermediate maturing

(421.1) and large framed-late maturing (352.2) cattle. In the same study, contemporaries to pasture cattle were placed in a feedlot, which resulted in numerically higher marbling scores for all biological types. Though comparisons were not made between feedlot and pasture cattle there was little numerical difference in the marbling scores of large framed-late maturing feedlot-finished steers, intermediate framed-early maturing pasture-finished steers, and small framed-early maturing pasture-finished steers (marbling scores were 501.1, 496.8, and 484.6, respectively).

Marbling is used as a visual indicator of palatability in the USDA quality grading system. In general, higher prices are given to carcasses with higher USDA marbling scores. This grading system works against forage-finished cattle since they will generally have lower marbling scores than contemporaries raised in a feedlot setting. This may not be a problem if grass-fed cattle can be sold in a separate market. In this case, some consumers may prefer leaner forage-finished cattle in comparison to highly marbled beef. A consumer study by Killinger et al. (2004a), found that consumers in Chicago (86.7%) and San Francisco (67.0%) visually preferred low marbling (Slight) steaks to high marbling (Moderate/Modest) steaks.

Lean Color

The basic pigment of meat is myoglobin. Upon exposure to air myoglobin is oxygenated to form the bright-red pigment oxymyoglobin, which is associated with "freshness" of meat and is attractive to consumers (Muir et al., 1998b). At lower partial pressures of oxygen, myoglobin oxidizes to an unattractive brown form known as metmyoglobin. Metmyoglobin formation is also affected by the chemically reducing conditions of the muscle, such as pH level and postmortem decline, and the amount of

oxygen within the muscle post-mortem (Renerre and Labas, 1987). Meat color is ultimately determined by level of pigmentation and the relative percentages of myoglobin, oxymyoglobin, and metmyoglobin formation in the muscle. When considering lean color of fresh meat we must consider two factors, color of fresh meat surface and rate of discoloration over time caused by formation of metmyoglobin. Color measurements are generally made through the use of visual appraisal or through the use of a spectrophotometer.

Typical lean color in young grain-fed cattle is bright cherry-red, while a darker color is associated with older animals and animals that have been stressed in the production process. Meat color is affected by the glycogen stores in the muscle that allow the pH of the muscle to drop post-mortem. It is reported that at least 57 umol/g of glycogen is needed for muscle pH to achieve the ultimate level of 5.5 in the post-mortem muscle (Thompson, 2002). If glycogen reserves have been depleted below this threshold then an elevated ultimate pH will result and the meat will have a dark color, which is typically referred to as dark cutting or dark firm dry (DFD) meat. As ultimate pH increases, the meat may become less juicy, lack visual appeal, and have reduced shelf life (Thompson, 2002). Consumer studies have indicated that consumers prefer bright cherry-red color to that of dark-red color when purchasing beef (Killinger et al., 2004a; Jeremiah et al., 1972).

Production factors and stress are two of the main factors that affect glycogen in the muscle at harvest. Glycogen reserves at slaughter are a function of initial levels of glycogen and the losses due to stresses placed on the animal during the immediate pre-slaughter period. Muir et al. (1998b) explains that in most studies comparing forage-

finished and grain-finished cattle there were no differences in lean color. This is supported by recent studies by French et al. (2001) and Mandell et al. (1997) who reported similar lean color in the *longissimus dorsi* muscle of forage-finished and concentrate-finished cattle. Other researchers have found differences in lean color between feeding regiments, finding that forage-finished cattle had darker color lean when compared with grain-fed cattle (Bennett et al., 1995; Bidner et al., 1986; Schroeder et al., 1980). Bidner et al. (1986) attributed the darker lean color in forage-fed animals to higher myoglobin concentrations. Muir et al. (1998a) indicated that grass-fed steers had higher ultimate pH values than grain-fed steers because grass-fed steers were more susceptible to pre-slaughter stress and would be more likely to suffer glycogen depletion in the factory pre-slaughter. Darker lean is associated with higher pH. It is possible that type of forage could have an affect on lean color. Schaake et al. (1993) found no difference in cattle raised on spring fescue-clover pasture and those finished in a drylot, but the cattle finished on summer pastures had a darker lean.

Tenderness

Tenderness is a function of production, processing, value adding and cooking method used to prepare the meat for consumption by the consumer. Failure of one or more links in the beef supply chain increases the risk of a poor eating experience for the consumer (Thompson, 2002). The consumer ultimately determines the eating quality of meat. Consumers have indicated that beef tenderness is an important attribute (Huffman et al., 1996), and Killinger et al. (2004b) found the correlation between tenderness and overall consumer acceptability to be 0.78. Research indicates that consumers can segregate differences in beef tenderness and are willing to pay more for more-tender beef

(Miller et al., 2001; Boleman et al., 1997). Miller et al. (2001) found that tenderness threshold classes (Shackelford et al., 1991) of < 3.0 kg (Tender), 3.0 to 4.3 kg (Slightly tender), and > 4.9 kg Warner-Bratzler shear (Tough) resulted in 100, 93, and 25% consumer satisfaction for New York strip steak tenderness, respectively. This research indicates that the transition from tender to tough beef occurs between 4.3 and 4.9 kg of WBS.

Koohmaraie (1992) reported that the myofibrillar (muscle) component and connective tissue (collagen) component are the two main components involved with meat tenderness. A number of antemortem and postmortem production factors have been associated with tenderness, including age of animal at slaughter, *Bos indicus* percentage, sex, carcass weight, ultimate pH, carcass chilling rate, marbling, aging, management of animal pre-slaughter, and cooking method (Thompson, 2002). Age of animal at slaughter, growth rate, and chilling rate seem to be the three factors most closely related to forage-finished beef tenderness, all of which are interrelated. In general, due to slower weight gains, forage-finished cattle finish at a chronologically older age. As animals become older, the cross-linkages between collagen increases and collagen becomes less soluble (Aberle et al., 2001). Bruce et al. (2004) attributed greater heat stability of intramuscular collagen in pasture- vs. grain-finished steers to significantly greater mean compression values for pasture-raised steers. Decreased growth rate resulted in pasture steers finishing at an older age, and increased exercise during foraging were given as explanations for increases in heat stability of collagen.

Overall, forage-finishing of cattle seems to have little effect on tenderness when compared to grain-finished animals, when animals are finished to similar weights and fat

thickness. In a review of 15 forage- vs. grain-based feeding systems studies, Muir et al. (1998b) found that in all experiments studied, except those by Purchas and Davies (1974), Bowling et al. (1977), and Morris et al. (1997), grain-feeding had no significant effect on tenderness when shear force measurements, sensory panel analysis, or both were utilized to determine tenderness. In all studies where grain-fed cattle and forage-fed cattle had similar tenderness measurements, cattle were harvested at either similar weights or fat thickness. In the study of Purchas and Davies (1974), sensory panel tenderness did not significantly differ between treatments, but shear force values were significantly higher for grain-fed carcasses in the *longissimus dorsi* and *semitendinosus* muscles. In the case of Bowling et al. (1977), forage- and grain-finished animals were compared with similar marbling scores. Shear force and sensory panel values both indicated that steaks from grain-finished animals were more tender than those from forage-finished animals, but differences in tenderness may have been due to significant differences in subcutaneous fat thickness between treatments (forage-fed 4.1 mm; grain-fed 8.4 mm) and the subsequent effect on carcass chilling rate and sarcomere shortening. It should also be noted that cattle in this study did not come from the same contemporary group. Morris et al. (1997) reported significantly higher shear force values for concentrate-fed cattle, indicating tougher meat. In this study, feed was restricted in the concentrate group so that cattle would gain at equivalent rates of those in the pasture group. Cattle in the pasture group had a greater amount of fat than those in the concentrate group, which once again shows that fat cover seems to be more important than feeding regiment in determining tenderness.

In studies where meat from forage-finished cattle has been tougher, it is thought to be due to cold shortening because carcasses of cattle finished on forage were lighter and had less subcutaneous fat (Bowling et al., 1977; Schroeder et al., 1980; Tatum et al., 1982). Koohmaraie et al. (1988) explained that subcutaneous fat insulates the *longissimus dorsi* muscle postmortem and slows its rate of cooling thus preventing cold-shortening. Muir et al. (1998b) concluded that chilling rate is only partly responsible for the relationship between fatness and meat tenderness in cattle carcasses. This indicates that chilling rate may play a small role in differences in tenderness found between grain- and forage-finished beef. In a study by May et al. (1992), they found that correlations for shear force with 2.5 h longissimus temperature, marbling score, days on feed, fat thickness, and carcass weight were -0.63, -0.61, -0.56, -0.55, and -0.53, respectively.

Researchers have studied the affect of electrical stimulation on grass-finished carcasses to improve tenderness. Most have found no difference in shear force of longissimus muscle between electrically-stimulated carcasses of cattle finished on grass or grain (Bruce et al., 2004; Xiong et al., 1996; Bidner et al., 1985). These results, however, do not agree with those of Schroeder et al. (1982), who found that electrical stimulation of carcasses of cattle finished on grass reduced their mean shear force, but did not make them as tender as cattle finished on grain.

Flavor

Fat has been shown to be the major contributor to flavor in beef. The volatile components of lipids within meat are major contributors to meat flavor (Elmore et al., 2004). Along with this, fatty acid composition is significantly correlated with flavor (Melton et al., 1982; Larick and Turner, 1990). In a review of the effect of forage-

feeding on beef flavor, Melton (1983) reported that the largest differences in flavor occurs between beef from steers directly off pasture and those finished on concentrate corn diets. Though flavor differences between diets are often confounded by differences in fats, tt is clear that forage-raised cattle have different fatty-acid profiles than those from grain-fed animals (Mitchell et al., 1991; Wood et al., 2002; French et al., 2000b).

The greatest sensory difference in beef from forage-fed and grain-fed steers appears to be in the flavor of the fat (Larick et al., 1987; Harrison et al., 1978). Trained sensory panels have characterized the flavor of forage-finished beef as being less acceptable in a number of ways; gamey (Larick and Turner, 1990), grassy (Larick et. al., 1987), and milky-oily (Melton et al., 1982). In a review of the effects of feeds on beef flavor, Melton (1990) reported that compared with high-energy concentrate diets, several types of grasses produced less desirable flavor or less beef flavor. The grasses mentioned were Flint hills pasture in Kansas, orchardgrass-clover, rye-oats-ryegrass, forage sorghum, bluegrass-clover, fescue, fescue-orchardgrass-clover, ryegrass-clover, arrowleaf clover, Bermuda-clover-sudan, millet and Coastal bermundagrass. When consumer panels have been used, no significant differences in flavor were found in beef from forage-fed and grain-fed cattle (Bidner et al., 1981; Chastain et al., 1985; Schupp et al., 1980). Melton (1983) suggested that the reason for similar beef flavor from both pasture and grain in a number of studies could be attributed to differences in sensory panel or possibly to high quality of pasture used in the study.

Schaake et al. (1993) found no difference in flavor desirability in cattle finished on either fescue-clover or summer pasture forages in comparison to those finished on grain. Sapp et al. (1999) found no difference in sensory panel scores for beef flavor

intensity between cattle finished on grain, pasture plus grain,or pasture, but significantly higher incidence of off flavor were reported by the panel in pasture cattle in comparison to the two other diet regimes.

Juiciness

The organoleptic parameter "juiciness' is considered an important component of beef acceptability, though not as highly correlated to consumer acceptability as tenderness and flavor (Killinger et al., 2004b; Thompson, 2004). Juiciness is related to the amount of moisture released from the meat during mastication and also to the degree of salivation induced (Lawrie, 1998).

In general, researchers have found little differences in juiciness when comparing forage- and grain-finishing systems (Schaake et al., 1993; Mandell et al., 1998; Simonne et al., 1996), in particular when harvest weights or backfat thickness were at a constant between groups (Muir et al., 1998b). Some studies have found increased juiciness in grain-finished in comparison to forage finished beef (Sapp et al., 1999; Hendrick et al., 1983). It is likely that in cases where juiciness sensory scores were greater in grain-fed cattle, the primary reason was a greater amount of intramuscular fat instead of feeding regiment. This is because increased intramuscular fat is often associated with increased juiciness (Savell et al. 1987), and is said to stimulate salivation and give the perception of increased juiciness in meat while chewing (Thompson, 2004). In contradiction to most findings, Bruce et al. (2004) found higher taste panel scores for juiciness in pasture-finished cattle in comparison to grain-finished cattle. Possible reasons for these results are greater cooking loss and lower overall acceptability in grain-fed cattle (conducted in Australia).

Overall Acceptability

In a review, Muir et al. (1998b) stated that beef of comparable quality can be obtained from cattle finished on forage-based diets, provided that acceptable carcass weights and degrees of finish can be achieved at a young age. They also found that there is wide variation in palatability results from forage- and grain-based research studies.

Geographical region may affect acceptability of forage-finished beef. Thompson (2004) found that juiciness and flavor scores were higher and comparable to feedlot cattle for pasture cattle harvested in south Australia in comparison to those harvested in the north. Slaughter age was given for the primary factor associated with this difference in pasture raised cattle from the South, with cattle in the South's performance being closer to that of feedlot cattle.

Few studies have been done to improve grass-fed beef flavor. Reverte et al. (2003) reported that the use of beef flavoring agents with muscle restructuring technology provides an effective means to enhance palatability of beef from an all forage-finishing systems.

Storage and Lipid Stability

Retail color has been found to deteriorate more rapidly for forage-fed than grain-fed beef (Craig et al., 1959; Reagan et al., 1977; Schroeder et al., 1980). Reagan et al. (1977) found that adding grain to pasture raised steers decreased surface discoloration and increased consumer desirability of steaks at day six of retail display. Contrary to some past results, Sapp et al. (1999) found similar discoloration rates in steaks from pasture, pasture/grain and grain-fed strip-loin steaks.

Studies have shown that pasture feeding can lead to increased concentrations of polyunsaturated fatty acids (PUFA), compared to grain-fed or supplemented beef (Larick and Turner, 1989; Srinivasan et al., 1998; Melton et al., 1982). Because of the higher PUFA concentration, it is possible that forage-finished beef is more susceptible to oxidation and may develop rancid off-flavors faster than grain-finished beef during refrigerated or frozen storage (Reverte et al., 2003).

Conclusion

Research indicates that forage-finished cattle have a number of disadvantages when compared to grain-finished cattle. Forage-finished beef is associated with lack of marbling, darker lean, yellow fat, poorer palatability characteristics (primarily flavor), and lack of cattle performance (Grienbenow et al., 1997). However, the review of literature indicates that for all of these problems there is research results that contradicts the disadvantages commonly associated with grass-fed beef. It is clear from prior studies that conflicting data has been reported during investigation on the impact of forage:concentrate ratios on beef quality (Muir et al., 1998b; O'Sullivan et al., 2004; Grienbenow et al., 1997). Interpreting data is further compounded when the various production factors are taken into consideration.

A positive side for forage-finished beef is that perception of meat quality differs between populations (Killinger et al., 2004a; Bruce et al., 2003; Savell et al., 1987). The combination of health benefits and an image of environmentally friendly production associated with finishing cattle on forages should provide an attractive alternative to health conscious consumers in comparison to traditionally raised U.S. beef. By controlling production factors, it seems as though a highly palatable beef product can be

produced on a forage-based system. Literature indicates little difference in palatability of forage vs. grain-fed beef when marbling, age at slaughter, and shear force is similar for animals (Thompson, 2004; Muir et al., 1998b). It is also evident that high quality forages and addition of concentrate may be necessary to produce cattle on a forage-based finishing system that will produce similar carcass traits in comparison to feedlot cattle (Schaake et al., 1993; French et al., 2000). Further research is needed to identify production factors that will allow producers to produce high quality forage-finished beef.

Research Objectives

The purpose of the research presented in this manuscript is to study the effects of finishing yearling steers, that would normally be placed in a feedlot, on high quality ryegrass forage with varying levels of supplemental corn to provide added energy in the diet. There are few studies that have analyzed the effect of animal supplementation within a forage-finishing system. A feedlot treatment was included in the study to determine cattle performance if they had been produced under normal production practices. Carcass traits and performance data from treatments will be compared with each other to determine the effect of diet on finishing of cattle for harvest. It is also likely that supplementation will affect forage quality and availability. Forage quality and availability will be collected over the finishing period to analyze these effects.

CHAPTER III

FORAGE QUALITY, ANIMAL PERFORMANCE, AND CARCASS TRAITS OF STEERS FINISHED ON WINTER ANNUAL RYEGRASS (*Lolium multiflorum* Lam.) PASTURE WITH VARYING LEVELS OF CORN SUPPLEMENTATION

Introduction

Finishing beef on a forage-based system has been discussed as an alternative to grain finishing in a feedlot, but to date forage-finishing of beef has not become a wide spread production system in the United States. In recent years, there has been an increased interest in forage-fed beef due to a growing niche market for natural and organic meats, along with health benefits associated with forage-fed beef. French et al. (2000b) found that forage-finished steers had a higher proportion of n-3 polyunsaturated fatty acids and CLA, increased polyunsaturated:saturated fatty acid ratio, and decreased n-6:n-3 fatty acid ratio in fat from longissimus muscle in comparison to concentrate-fed steers.

Past research has found a number of problems associated with the use of forage in comparison to concentrate as the primary feed source when finishing cattle. Lower ADG, longer finishing period to reach target endpoint, lower dressing percentage, less acceptable lean and fat scores, and lower quality grade has been found for forage-finished cattle (Bidner et al., 1981, 1986). Researchers have found palatability issues, primarily

related to flavor, when comparing animals finished on all forage diet with those finished on a high concentrate diet (Melton, 1990; Bowling et al., 1977, 1978).

Greinbenow et al. (1997) points out that there is conflicting research related to most of the problems associated with forage-finished beef, and Muir et al. (1998) concluded that the feeding system has no or little effect on palatability traits and carcass traits when cattle are finished to similar carcass weight or same degree of fatness. This suggests there may be methods of producing forage-finished beef that results in acceptable consumer satisfaction, animal performance, and/or carcass characteristics. Little research has studied the effect of adding concentrate to pasture diets for finishing cattle. The objective of this study was to determine the effect of adding concentrate to pasture diets on carcass traits, palatability traits, and forage utilization.

Materials and Methods

Experimental Design

Crossbred steers (N=72) were selected from the resident herd at the E.V. Smith Beef Unit and randomly assigned to one of six finishing treatment diets. Steers for the study were born between November 2002 and February 2003. Following weaning, steers were backgrounded on a mixed ration of hay plus concentrate diet until placed into finishing treatments in December 2003. Non-implanted steers were finished on either ryegrass pasture with various levels of supplement or in a dry lot with ad-libitum access to a high concentrate diet. Pasture supplemented treatments received whole shelled corn (*Zea mays*) supplemented as a percentage of pen bodyweight. Diets consisted of ryegrass pasture plus corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), 2.0%

(2.0) of bodyweight, or ad-libitum concentrate diet in drylot (GRAIN). Cattle were stratified based on breed of sire and randomly assigned to a pen (N=18). One Angus sired, two Charolais sired, and one Brangus sired steer were placed in each pen. As a result, there were 4 animals/pen and 12 animals/treatment.

Pen served as the experimental unit and therefore each treatment was measured in triplicate. In December 2003, cattle were allotted to pens. Steers were given a one week adjustment period and initial weights were recorded. Following initial weigh date, steers were weighed every 28 d to adjust feed and track performance, with exception of a 35 d weigh period between March and April due to bad weather. Three animals were removed from the study, two due to illness, and one due to injury prior to harvest. A steer of similar weight was substituted for steers removed due to illness, but not used for statistical analysis.

Ryegrass (*Lolium multiflorum* Lam.) pasture pens (N=15) measuring 1 ha each were used as the primary forage source for all pasture treatments. Marshall™ ryegrass was planted in September at a seeding rate of 33.6 kg ha^{-1}. Nitrogen was applied at a rate of 110 kg ha^{-1} at planting and an additional 65 kg ha^{-1} was applied in late February. Whole shelled corn was used to supplement pasture treatments, based on the pen average percentage of body weight for their respective treatment. Supplement was fed daily only when each pen had completely consumed feed from previous day. Cattle from the feedlot treatment were placed in three drylots of similar size. Feedlot cattle received free choice feed throughout study. For the first month of the study, cattle were pre-conditioned on an ad-libitum corn silage diet. Following the January weigh period, animals in the feedlot pens were placed on a mixed diet consisting of 65% shelled corn,

15% cotton seed hulls, 12.5% protein supplement (Nutrabeef™; Table 1), 5% soybean meal, and 2.5% molasses.

Body weights, ADG, daily feed intake (corn consumption of pasture treatments and mixed grain ration of drylot treatment), and feed consumption as a percent body weight for monthly feeding periods are summarized in table 2. Final BW prior to harvest, total feed consumption during finishing period, and average daily feed intake and intake as a percent body weight for the entire finishing period are also summarized in the table.

Aloka 500 real-time ultrasound machine with a 17.2 cm 3.5 MHz linear transductor (Corometrics Medical Systems, Wallingford, CT) was used during weigh period to estimate average pen backfat thickness. Cattle were harvested by pen when the estimated average pen backfat thickness reached 6.35 mm. Cattle were weighed and blood samples were taken when the pen was ready to harvest. Cattle were then transported to Lambert Meat Laboratory where they were inspected by a USDA inspector and humanely slaughtered following USDA regulations and the Humane Slaughter Act. Cattle were harvested two or three pens at a time on a weekly basis from April 27 to June 15, 2004.

Carcass Evaluation

Following harvest, hot carcass weight (HCW) was recorded and carcasses were placed in chill cooler at 2 ± 1ºC. At 48 h post mortem the right side of each carcass was ribbed between the 12th and 13th ribs for carcass evaluation. Carcasses were analyzed by trained evaluator to determine quality and yield factors (USDA, 1997). Preliminary yield grade (PYG) was determined by measuring fat thickness over the longissimus muscle at

¾ of the distance from the medial edge, and adjusted as appropriate to determine adjusted preliminary yield grade (APYG). The longissimus muscle area (LMA) was measured using a plastic grid to the nearest tenth of an inch. Estimated kidney, pelvic, and heart fat (KPH) was visually evaluated and yield grade was determined to the nearest tenth using a yield grade formula. Degree of marbling was scored on a scale of 100 to 600, where 100 = practically devoid^{00} and 600 = moderate^{00}. Lean maturity and skeletal maturity was scored on a scale starting at 100, where 100 = A^{00} and 200 = B^{00}.

Ribeye rolls were removed from the right side of each carcass following grading. Ribeye rolls were labeled, vacuum packaged in oxygen barrier bags (Cryovac®, Duncan, SC), and held at 2 ± 1ºC. At 21 d ribeye rolls were removed from bag and four steaks were cut starting at the loin end. The first steak removed was cut to straighten the longissimus muscle (LM) face and used for proximate analysis. The following three LM steaks were cut 2.54 cm thick. The first steak was used for sensory analysis, the second for Warner-Bratzler shear (WBS) force analysis, and the third steak was kept for a backup. After removing steaks the remaining ribeye roll was vacuum packaged and placed in the cooler for further aging. At 42 d and 84 d post mortem, two 2.54 cm-thick steaks were removed for sensory and WBS analysis, respectively. All individual steaks were labeled, vacuum packaged, and placed in a freezer at < -10ºC until further analysis.

Shear Evaluation

Warner-Bratzler shear force values were determined according to AMSA (1995) guidelines. Frozen steaks were randomly selected, removed from the freezer, and allowed to thaw for 24 h at 3 ± 1ºC. Steaks were removed from the vacuum package and cooked on a clam-shell-style grill (George Foreman Grilling Machine, Lake Forest, IL) to an

internal temperature of 71ºC (medium degree of doneness). Steaks were labeled, covered in aluminum foil, and chilled at 3 ± 1ºC for 24 h. Six cores (1.3 cm in diameter) were removed from the LM parallel to the muscle fiber orientation. Each core was sheared once across the middle, perpendicular to the muscle fiber orientation using a Warner-Bratzler shear machine (model 1955; GRE Manufacturing, Manhattan, KS). The peak force measurements of the six cores from each steak were averaged for statistical analysis.

Sensory

A trained sensory panel (6 to 7 members) evaluated LM steaks (aged 21 d) from the rib section (AMSA, 1995). Randomly selected frozen steaks were thawed at 3 ± 1ºC for 18 h and cooked on a clam-shell grill (George Foreman Grilling Machine, Lake Forest, IL) to an internal temperature of 71ºC (medium degree of doneness). Samples were trimmed of outside fat and connective tissue, cut into 1.27 cm^2 portions using a plastic grid, and placed in warming pans until served to panelist. Steak samples were evaluated for initial and sustained juiciness, initial and sustained tenderness, flavor intensity, and beef flavor on a scale of 1 to 8, where 1 = extremely dry, tough, bland, and uncharacteristic, and 8 = extremely juicy, tender, intense, and characteristic, respectively. Two samples from each steak were evaluated by panelists that were secluded in partitioned booths with controlled levels of red incandescent light. A warm-up sample steak was served at initiation of each sensory session, followed by six to eight steak samples per session. Panelists were instructed to cleanse palate by taking a bite of saltless saltine crackers and a drink of water before each sample. Longissimus muscle

steaks from 42 and 84 d postmortem aging groups were determined to be unacceptable for sensory analysis due to off-odors.

Chemical Analysis of Longissimus Muscle

Chemical composition of LM from the 12th rib section was performed to determine moisture, fat, ash, and protein percentages within the muscle. Samples were removed from the freezer and thawed for 24 h at 3 ± 1ºC. Steaks were removed from the vacuum package and trimmed of all exterior fat and connective tissue. The LM was then placed in a Waring™ two-speed laboratory blender (Waring Laboratory, Torrington, CT) until a uniform paste was achieved. Moisture and fat was determined using the SMART Trac™ Moisture and Fat Analyzer system (CEM Corporation, Matthews, NC) and ash was determined using a Phoenix microwave muffle furnace (CEM Corporation, Matthews, NC). Protein was determined for individual samples by subtracting ash, moisture and fat percentages. All data was reported on a percentage basis.

Forage Mass

Disk meter measurements were taken monthly to determine forage mass and availability in relationship to supplement treatment and month of study. Disk meter height (DH) measurements were taken according to procedures described by Bransby et al. (1977) on a monthly basis from the month of Dec. 2003 to Apr. 2004 (approximately 28 d interval). Measurements were made with a 1.36 kg disk. The disk area and diameter measured 0.17 m^2 and 0.46 m, respectively. Approximately 30 readings per paddock (1 ha) were collected at random by making a zigzag pattern across the paddock. Readings from each paddock were averaged for statistical analysis.

Disk meter calibrations were made at the beginning (Dec) and end (Apr) of the study to establish a linear relationship between disk meter height (DH) and dry matter mass (DMM). Ten paired samples of DH and dry matter samples were taken per calibration to represent the range of meter readings for that period. The sampling procedure involved taking an initial reading with the meter, placing a circular quadrant corresponding to the size of the disk over the area sampled, and clipping the material within the quadrant with hand held clippers. Dry weights were then determined using partial dry matter procedures. The regression relationship of available forage dry matter (kg/ha) to disk meter height was DMM = (6.3229 + 3.3247*DH)*61.132 and DMM = (11.517 + 2.9554*DH)*61.132 for Dec. and Apr. calibrations, respectively. December calibration equation was used to predict forage mass in the months of Dec., Jan., and Feb., and the April calibration equation was used for the months of Mar. and Apr. The coefficient of determination was 0.8909 and 0.9099 for Dec. and Apr. calibrations, respectively.

Chemical Analysis of Forage

Forage samples were collected on a monthly basis (January to May 2004) in conjunction with cattle weigh dates. Forage samples were randomly grabbed across pen and placed in brown paper bags. Samples were dried for 48 h at 55°C in a convection oven (NAPCO; model 420) and weighed prior to drying and after drying (equilibrated to room temperature for 24 h) to determine partial dry matter. Partially dry samples were ground in a Thomas-Willey mill (Thomas Scientific; model 4) to pass through a 1 mm mesh screen, labeled, and placed in sealed plastic containers. Chemical analysis was conducted on ground samples to determine dry matter (DM), ash, neutral detergent fiber

(NDF), acid detergent fiber (ADF), and crude protein (CP). Methods described by AOAC (1998) were used to determine DM, ash, and CP. Nitrogen was determined by using a LECO TruSpec® (Leco Corporation, St. Joseph, MI) and multiplied by 6.25 to estimate CP. NDF and ADF were determined on samples according to Van Soest et al. (1991) using an ANKOM^{200} fiber analyzer and ANKOM F57 filter bags (ANKOM Technology Corp., Fairport, New York).

Statistical Analysis

Data was analyzed as a completely randomized design using GLM procedure of SAS (1998). Pen replicate within finishing treatment was used to test differences between finishing treatments for all carcass and animal production data. Forage data was analyzed where pen replicate within finishing treatment and month were used to test differences between finishing treatments, months, and treatment x month interaction. Significant ($P \leq 0.05$) main and interaction effect means were separated with Fisher's protected LSD using the PDIFF option of LSMEANS in SAS.

Results

Animal performance and carcass traits

Diet did not significantly affect average daily gains (ADG, $P = 0.24$) or days on finishing diet ($P = 0.23$) to reach target endpoint (days on feed, Table 3). ADG ranged between 0.95 and 1.27 kg d^{-1} for 0.5 and 1.5 treatments, respectively. Steers finished on 2.0 and GRAIN diet had higher ($P < 0.05$) dressing percentages than those in the 0.5 and 0.0 treatments. Dressing percentage from 1.0 and 1.5 was not significantly different ($P > 0.05$) than 0.5, 2.0, and GRAIN steers, but was higher ($P < 0.05$) than the 0.0 treatment.

No significant differences ($P > 0.05$) were found among diets for hot carcass weight, skeletal maturity, lean maturity, marbling, preliminary yield grade (PYG), longissimus muscle area (LMA), and KPH fat percentage. Marbling scores tended to be highest ($P = 0.16$) for the GRAIN treatment (slight^{69}) followed by pasture-raised steers receiving 1.5 % of their bodyweight in corn supplement (slight^{60}). Pasture raised steers receiving 0.0, 0.5, and 1.0% of their bodyweight in supplemental feed had lower ($P < 0.05$) adjusted PYG than pasture steers receiving 1.5% supplementation. Steers finished on an ad-libitum concentrate diet had a higher ($P < 0.05$) yield grade than those in the 0.0, 0.5, and 1.0 pasture treatments. Yield grades for 1.0 steers was lower ($P < 0.05$) than that of 1.5 and 2.0 steers in addition to those in the GRAIN treatment.

Warner-Bratzler shear and sensory traits

No significant differences ($P > 0.2$) were found in Warner-Bratzler shear (WBS) measurements among diets for all three aging treatments; 21, 42, and 84 d postmortem (Table 3). Sensory panel scores (21 d postmortem) among diets were similar ($P > 0.05$) for initial juiciness, sustained juiciness, initial tenderness, flavor intensity, and beef flavor. Sustained tenderness scores were lower ($P < 0.05$) for steers finished on the 1.0 diet than they were for 0.0, 0.5, 1.5, 2.0, and GRAIN treatments.

Chemical analysis of longissimus muscle

Longissimus muscle percent moisture was higher ($P < 0.05$; Table 4) in 0.0, 0.5, and 1.0 treatments than 1.5, 2.0, and GRAIN treatments. No significant differences ($P > 0.13$) in chemical composition of LM among diet treatments were found for intramuscular fat, ash, or protein percentages.

Forage Mass

Dry matter forage mass (DMM) was determined on a monthly basis from December to April using disk meter height readings from forage paddocks (Fig. 1). Using diet x month interaction, no significant differences ($P > 0.05$) in DMM were found among diets within December, January, and February sample dates. In March more ($P < 0.05$) forage mass was found in 0.5 and 2.0 treatments than that of 0.0. In April, an incremental increase ($P < 0.05$) in DMM (3312 kg ha^{-1} to 6973 kg ha^{-1}) within paddocks was found with each increase in the amount of supplemental grain.

Chemical analysis of forage

Ash (Fig. 2) percentage of forage was higher ($P < 0.01$) in 0.0 paddocks than in 0.5, 1.0, 1.5, and 2.0 treatments. Monthly effect resulted in lower ash percentage ($P < 0.05$) in May than all other sample dates. Ash percentage was higher ($P < 0.05$) in March and February than it was in January. NDF within paddocks increased ($P < 0.01$, Fig. 3) on a monthly basis from 32% (Jan) to 61% (May). ADF within paddocks increased ($P < 0.001$, Fig. 4) on a monthly basis from 15% (Jan) to 32% (May). Using diet x month interaction, diet did not affect ($P > 0.05$) protein (Fig. 5) in January, February, April, and May sample dates. March sample date resulted in lower ($P < 0.001$) protein percentage in 1.0 and 1.5 than 0.0 and 0.5 treatments. Protein for 1.5 was similar ($P > 0.05$) to 0.0, 1.0 and 2.0 paddocks, but lower ($P < 0.05$) than 0.5 treatment for the March sample date.

Discussion

Animal Performance and Carcass traits

Mandell et al. (1997) noted that many studies comparing forage vs. grain finishing have been confounded regarding backfat finish and days on feed. In those studies, forage-fed cattle often had minimal amounts of finish or were slaughtered at ages older than those of grain-fed cattle. In a review of forage- and grain-based feeding systems, Muir et al. (1998b) attributed most differences in carcass traits and palatability found in past research to differences in average daily gain and degree of fatness. In the current study, there were no differences in average daily gains and days on feed. A number of researchers found decreased weight gains in forage-finished cattle resulting in a longer finishing period to reach the same weight or backfat thickness as those finished on grain (Bidner et al., 1981, 1986; Mandell et al., 1997; French et al., 2001). Similar average daily gains across treatments may explain the few differences in carcass and palatability traits found in this study. This agrees with French et al. (2000), who showed that when steers had similar mean rates of carcass growth, finishing diet *per se* (grass, concentrate, or silage) did not affect sensory traits. The current study contradicts Bidner et al. (1981), who found no difference in live weight gains between steers finished on grass supplemented with grain (whole shelled corn) and those finished on grain, while steers finished on grass pastures alone had lower daily weight gains. In that study, forage finished steers had less subcutaneous fat and lower marbling scores, but there were no differences in shear force scores and sensory attributes.

The current study agrees with Bidner et al. (1986) and McMillin et al. (1990) who found lower dressing percentages and yield grades in steers receiving lower amounts of concentrate in their diet. A number of researchers have found higher marbling scores in cattle finished on a primarily grain diet (Crouse et al., 1984; Reagan et al., 1981; Bidner et al., 1986). In these studies, increased marbling is attributed to increased fatness in grain-finished cattle. In the present study, the two treatments that reached the target end point in the fewest days had the highest numerical marbling scores. This indicates differences in marbling scores may have been greater if cattle were harvested at a set days on feed instead of a constant backfat.

Warner-Bratzler shear and sensory traits

WBS tenderness measurements agree with most forage- vs. grain-finished research. Most studies indicate no difference in tenderness scores among diets (Muir et al., 1998; French et al., 2001; Schaake et al., 1993). However, others (Bowling et al., 1977; Schroeder et al., 1980; Bennett et al., 1995) found forage feeding to increase shear force compared with grain feeding.

Besides sustained tenderness, no differences ($P > 0.05$) in sensory panel scores were found in this study. The lower sustained tenderness scores for 1.0 treatment may be attributed to this group having the lowest numerical marbling score and highest numerical WBS score at 21 d post-mortem. Sensory scores from this study agree with Bidner et al. (1981 and 1986), French et al. (2001), and Crouse et al. (1984) who have found no differences in palatability attributes between forage- and grain- finished cattle. Muir et al. (1998b) found that few researchers have found differences in taste panel tenderness, juiciness, and flavor ratings between forage- and grain- finished cattle harvested either at

similar weight or fat covering. While tenderness and juiciness scores agree with most studies that have examined forage vs. grain feeding, the effect of diet on flavor attributes seems unclear. Forage-finishing has been attributed to lower flavor scores and increased incidence of reported off-flavors (Mandell et al., 1998; Melton, 1990; Larick et al., 1987). In the current study, while there were no significant differences among treatments, flavor scores increased with increased concentrate in the diet.

Chemical analysis of longissimus muscle

Concentration of grain in the diet had an effect on the moisture content within the LM at the 12th rib section. Moisture content was higher for steers receiving a higher concentration of grain in the diet (1.5, 2.0, and GRAIN). This agrees with Schaake et al. (1993) who found that pasture-fed steers had greater percentage of moisture in the lean tissue. There were similar fat percentages among treatments which can be attributed to similar marbling scores. No difference in protein and ash among treatments agrees with past research comparing forage- and grain-finishing (O'Sullivan et al., 2003; Schaake et al., 1993; Schroeder et al., 1980)

Forage quality and mass

Forage quality as indicated by NDF, ADF, and protein percentages was similar across treatments which is consistent with past studies that have found few differences in forage quality between various grazing treatments (Syfrett, 2003). The greater concentration of ash in the 0.0 treatment may be explained by lower forage mass resulting in lower plant height. When sampling it is plausible that the lower plant height resulted in increased trampling by cattle and a greater chance to include feces in the sample. It is also possible the lower plant height made it more difficult for the sampler to

discard soil material. The greatest decrease in forage quality resulted from the April to May sampling period. There was a significant increase in NDF (42.3% to 61.3%) and ADF (21.4% to 32.9%) and decrease in protein (19.8% to 10.5%) during this period. High NDF is negatively correlated with digestible energy and would likely become the first limitation to increased animal production (Redfearn et al., 2002; NRC, 1996). The high forage quality throughout most of the study allowed steers on an all forage diet to have similar ADG as those receiving supplemental grain and steers in the feedlot.

Increased grain supplementation resulted in greater amounts of forage mass availability. These results were expected, as corn supplementation would likely decrease forage consumption. In the higher supplementation groups there was a larger amount of un-harvested forage as indicated by the April disk meter readings. The available forage for steers in the 1.0, 1.5, and 2.0 paddocks was considerably higher than that of past researchers in the month of April, while forage availability in the 0.0 paddocks was closer to past research results (Hafley et al., 1996; Redfearn et al., 2002). This indicates that an increased amount of steers per hectare could have been placed in the high supplementation groups to fully utilize available forage

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Implications

The results of this study indicate that supplementation of finishing steers on annual ryegrass had little effect on animal performance, carcass traits, and palatability attributes. Forage quality was similar among treatments. Forage availability increased

with the addition of corn to the diet, as indicated by higher DM forage mass in latter months for treatments receiving increased amounts of supplementation.

CHAPTER IV.

TABLES AND FIGURES

Table 1. As-fed feed analysis of Nutrabeef™ feedlot finisher concentrate pellet.

Active Drug Ingredient	
Lasalocid	240 grams/ton
Guaranteed Analysis	
Crude Protein	Min. 41.0 %
Crude Fat	Min. 1.0 %
Crude Fiber	Max. 10.0 %
Calcium	Min. 7.25% Max. 7.75 %
Phosphorous	Min. 0.95 %
Salt	Min. 4.5 % Max. 5.5 %
Sodium	Min 1.8 % Max. 2.4 %
Potassium	Min. 1.75 %
Vitamin A	Min. 35,000 IU/LB

Table 2. Body weight, ADG, daily feed intake, and feed consumption as percent body weight of steers ryegrass pasture with varying levels of supplementation, or ad-libitum mixed ration grain diet in drylot.

Feeding Period[b]		Diet[a]					
		0.0	0.5	1.0	1.5	2.0	GRAIN
Dec	BW (kg)[c]	319	323	314	328	315	312
	ADG (kg)	1.40	0.82	1.03	1.12	0.66	-0.34
	Daily feed[d]	-	1.16	1.70	1.58	2.2	-
	% BW[d]	-	0.36	0.54	0.44	0.71	-
Jan	BW[c]	358	346	343	360	333	302
	ADG	1.04	0.85	0.97	1.01	1.11	2.49
	Daily feed	-	1.74	3.28	4.93	4.75	-
	% BW	-	0.50	0.96	1.37	1.43	-
Feb	BW	388	370	370	388	364	372
	ADG	0.89	0.73	0.83	1.10	1.31	1.38
	Daily feed	-	1.85	3.62	5.71	6.78	-
	% BW	-	0.5	0.98	1.48	1.87	-
Mar	BW	412	390	393	419	401	411
	ADG	1.07	1.24	1.67	1.49	1.26	1.47
	Daily feed	-	1.93	3.93	6.27	7.48	-
	% BW	-	0.5	1.0	1.5	1.91	-
Apr	BW	449	432	449	470	444	461
	ADG	1.31	1.39	1.24	2.26	2.19	1.11
	Daily feed	-	2.13	4.36	7.03	8.75	-
	% BW	-	0.49	0.97	1.50	1.98	-
May[f]	BW	486	471	481	-	-	-
	ADG	0.53	0.46	0.34	-	-	-
	Daily feed	-	2.32	4.76	7.94	10.32	-
	% BW	-	0.50	1.00	1.50	2.00	-
Total	Final BW	498	482	493	515	500	491
	ADG	1.04	0.95	1.14	1.28	1.16	1.20
	Feed[g]	0	3758	6635	8848	11572	17318
	Daily feed	-	1.85	3.51	5.13	6.21	9.73
	% BW	-	0.46	0.87	1.22	1.53	2.42

[a] Diets consist of ryegrass pasture plus corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), 2.0% (2.0) of bodyweight, or ad-libitum concentrate diet in drylot (GRAIN)

[b] Weigh dates (~ every 30 d) for feed adjustment, beginning with initial weigh date (December 12, 2003).

[c] Body weight (kg) at beginning of feeding period

[d] Average daily feed consumption (kg/d) per animal (excluding pasture consumption)

[e] Feed consumption based on average percent body weight

[f] Missing data due to pens taken to harvest prior to weigh date. ADG for 0.5 and 1.0 groups is the average of two pens

[g] Total feed consumption (kg) over finishing period

Table 3. Least squares means ± SEM for performance and carcass traits of steers finished on ryegrass pasture with various levels of supplementation or ad-libitum mixed ration grain diet in drylot.

	Treatment[a]						
Variable	0.0	0.5	1.0	1.5	2.0	GRAIN	P > F
Days on feed[b]	172 ± 8.5	169 ± 8.5	158 ± 8.9	143 ± 8.5	155 ± 8.9	151 ± 8.5	0.23
Average daily gain, kg d^{-1}	1.04 ± 0.093	0.95 ± 0.093	1.16 ± 0.098	1.27 ± 0.093	1.16 ± 0.098	1.20 ± 0.093	0.24
Dressing percentage	56.3^{x} ± 0.73	57.3^{xy} ± 0.73	58.6^{yz} ± 0.77	58.6^{yz} ± 0.76	60.6^{z} ± 0.77	60.1^{z} ± 0.77	0.013
Hot carcass wt, kg	280 ± 7.8	275 ± 7.8	290 ± 8.2	300 ± 7.8	300 ± 8.2	297 ± 8.2	0.18
Skeletal Maturity[c]	130 ± 2.3	130 ± 2.3	133 ± 2.4	138 ± 2.3	135 ± 2.4	136 ± 2.4	0.14
Lean Maturity[c]	160 ± 5.8	153 ± 5.8	160 ± 6.1	153 ± 5.8	151 ± 6.1	152 ± 6.1	0.81
Marbling[d]	339 ± 17.2	318 ± 17.2	303 ± 18.2	360 ± 17.2	339 ± 18.2	369 ± 18.2	0.16
PYG[e]	2.47 ± 0.084	2.56 ± 0.084	2.45 ± 0.088	2.78 ± 0.084	2.69 ± 0.088	2.68 ± 0.088	0.10
Adjusted PYG[e]	2.48^{y} ± 0.077	2.54^{y} ± 0.077	2.45^{y} ± 0.081	2.82^{z} ± 0.077	2.67^{yz} ± 0.081	2.69^{yz} ± 0.081	0.045
LM area, cm^2	74.6 ± 1.50	75.9 ± 1.50	78.6 ± 1.58	80.0 ± 1.50	78.7 ± 1.58	73.8 ± 1.58	0.075
KPH fat, %[f]	2.2 ± 0.12	2.2 ± 0.12	1.9 ± 0.12	2.4 ± 0.12	2.4 ± 0.12	2.3 ± 0.12	0.13
Yield Grade	2.11^{xy} ± 0.098	2.08^{xy} ± 0.098	1.94^{x} ± 0.103	2.40^{yz} ± 0.098	2.34^{yz} ± 0.103	2.54^{z} ± 0.103	0.009

[a] Diets consist of ryegrass pasture plus corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), 2.0% (2.0) of bodyweight, or ad-libitum concentrate diet in drylot (GRAIN).

[b] Days on final finishing diet.

[c] Maturity score ($100 = A^{00}$, $200 = B^{00}$).

[d] Marbling score ($300 = slight^{00}$, $400 = small^{00}$).

[e] Preliminary yield grade (2 = 0 mm, 3 = 10.2 mm fat opposite the ribeye).

[f] Estimate of kidney, pelvic, and heart fat.

[x,y,z] Means in row lacking common superscript letter differ ($P < 0.05$).

Table 4. Least squares means ± SEM for Warner-Bratzler shear and sensory panel traits of steers finished on ryegrass pasture with various levels of supplementation or ad-libitum mixed ration grain diet in drylot.

	Treatment[a]						
Variable	0.0	0.5	1.0	1.5	2.0	GRAIN	P > F
WBS 21 d[b], kg	4.4 ± 0.49	3.9 ± 0.49	4.5 ± 0.51	3.3 ± 0.49	4.0 ± 0.51	4.1 ± 0.51	0.60
WBS 42 d[b], kg	4.1 ± 0.39	3.6 ± 0.39	4.0 ± 0.37	2.9 ± 0.37	3.2 ± 0.39	4.0 ± 0.39	0.23
WBS 84 d[b], kg	2.9 ± 0.25	3.1 ± 0.25	3.0 ± 0.26	2.8 ± 0.25	3.0 ± 0.26	3.0 ± 0.26	0.97
Initial juiciness[c]	5.8 ± 0.16	5.6 ± 0.16	5.3 ± 0.17	5.5 ± 0.16	5.4 ± 0.17	5.9 ± 0.17	0.12
Sustained juiciness[c]	5.5 ± 0.18	5.2 ± 0.18	5.1 ± 0.19	5.2 ± 0.18	5.2 ± 0.19	5.6 ± 0.19	0.43
Initial tenderness[d]	5.6 ± 0.16	5.9 ± 0.16	5.4 ± 0.16	6.0 ± 0.16	5.9 ± 0.16	6.2 ± 0.16	0.065
Sustained tenderness[d]	5.6^{y} ± 0.19	5.5^{y} ± 0.19	4.9^{z} ± 0.20	5.7^{y} ± 0.19	5.6^{y} ± 0.20	6.0^{y} ± 0.20	0.043
Flavor intensity[e]	5.7 ± 0.11	5.6 ± 0.11	5.6 ± 0.11	5.7 ± 0.11	5.9 ± 0.11	6.0 ± 0.11	0.12
Beef flavor[f]	5.1 ± 0.20	5.3 ± 0.20	5.2 ± 0.21	5.4 ± 0.20	5.4 ± 0.21	5.8 ± 0.21	0.27

[a] Diets consist of ryegrass pasture plus corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), 2.0% (2.0) of bodyweight, or ad-libitum concentrate diet in drylot (GRAIN).
[b] Warner-Bratzler shear aged 21 d (WBS 21 d), 42 d (WBS 42 d), and 84 d (WBS 84 d).
[c] Scored on an 8-point scale (5 = slightly juicy, 6 = moderately juicy).
[d] Scored on an 8-point scale (5 = slightly tender, 6 = moderately tender).
[e] Scored on an 8-point scale (5 = slightly intense, 6 = moderately intense).
[f] Scored on an 8-point scale (5 = slightly characteristic, 6 = moderately characteristic).
[y,z] Means in row lacking common superscript letter differ (P < 0.05).

Table 5. Least squares means ± SEM for chemical composition of LM from steers finished on ryegrass pasture with various levels of supplementation or ad-libitum mixed ration grain diet in drylot.

	Treatment[a]						
Variable	0.0	0.5	1.0	1.5	2.0	GRAIN	P > F
Moisture[b]	72.4[y] ± 0.27	72.4[y] ± 0.27	72.7[y] ± 0.29	71.1[z] ± 0.27	71.5[z] ± 0.29	71.2[z] ± 0.27	0.005
Intramuscular fat[b]	2.7 ± 0.35	2.5 ± 0.35	2.2 ± 0.37	3.1 ± 35	3.0 ± 0.37	3.4 ± 0.35	0.22
Ash[b]	1.70 ± 0.035	1.78 ± 0.035	1.72 ± 0.037	1.74 ± 0.035	1.62 ± 0.037	1.70 ± 0.035	0.14
Protein[b]	23.1 ± 0.37	23.4 ± 0.37	23.4 ± 0.39	24.1 ± 0.37	23.9 ± 0.39	23.6 ± 0.37	0.53

[a] Diets consist of ryegrass pasture plus corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), 2.0% (2.0) of bodyweight, or ad-libitum concentrate diet in drylot (GRAIN).

[b] Percentage of longissimus muscle from 12th rib section

[y,z] Means in row lacking common superscript letter differ ($P < 0.05$).

Fig. 1. Least squares means for monthly distribution of forage yield (kg DM ha^{-1}) using disk meter readings of ryegrass paddocks grazed by steers receiving corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), or 2.0% of bodyweight (SEM = 248).

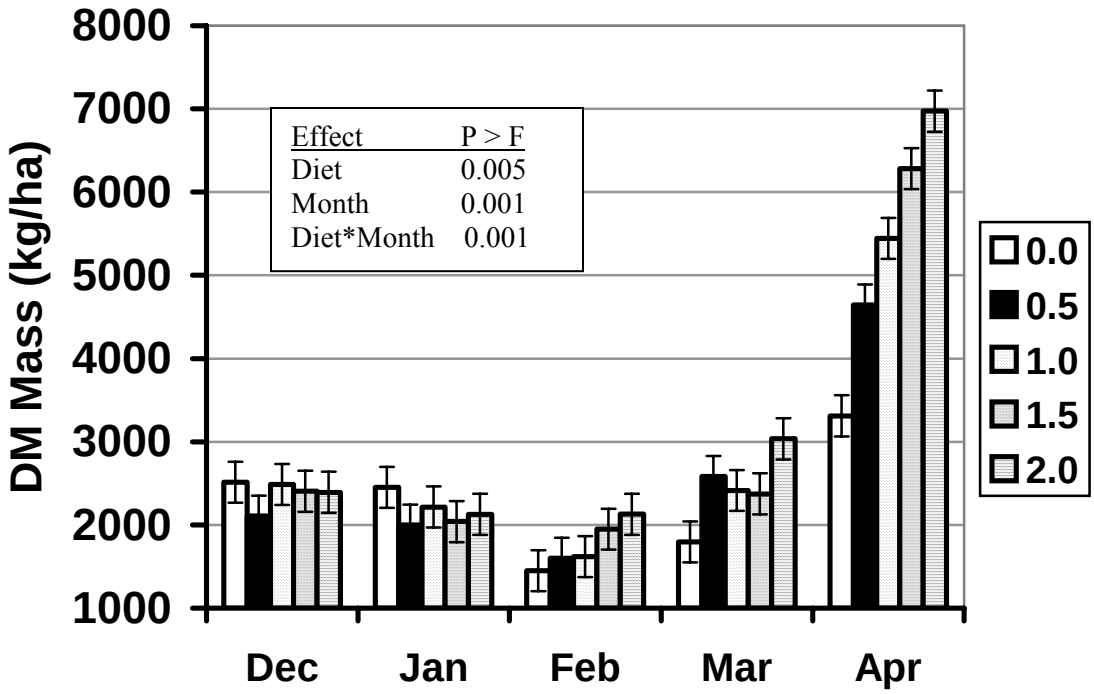


Figure 2: Least squares means for percent ash of samples from ryegrass paddocks grazed by steers receiving various levels of corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), or 2.0% (2.0) of bodyweight.

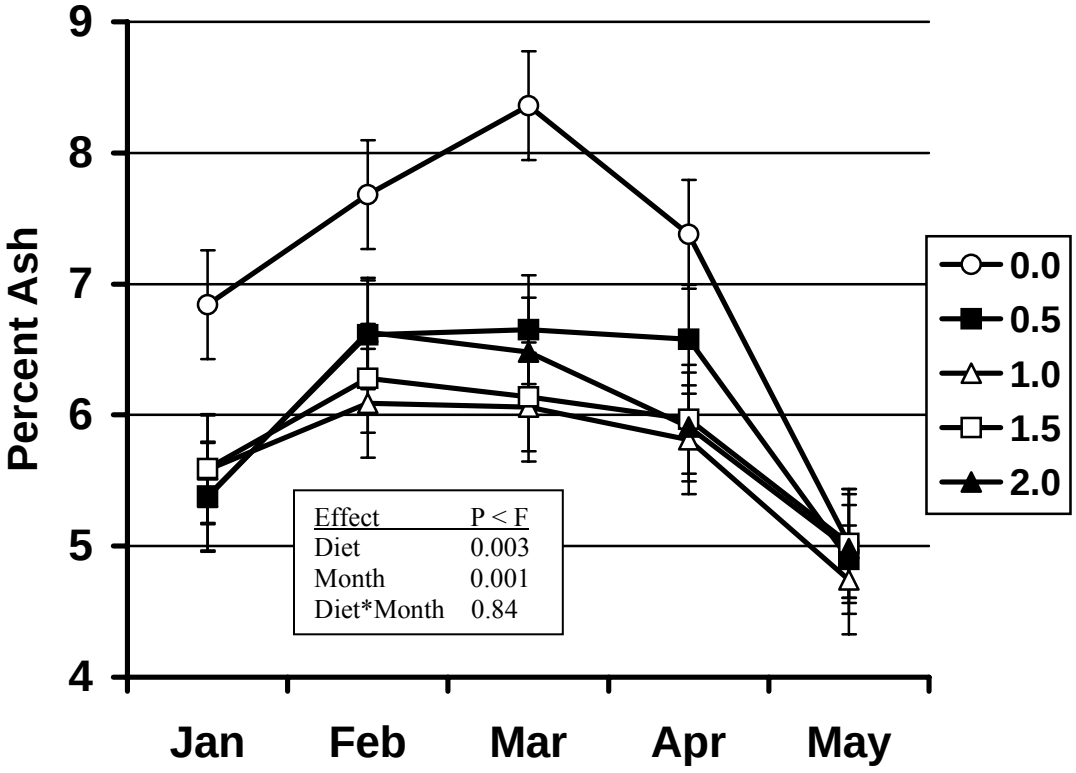


Figure 3: Least squares means for percent neutral detergent fiber (NDF) of samples from ryegrass paddocks grazed by steers receiving various levels of corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), or 2.0% (2.0) of bodyweight.

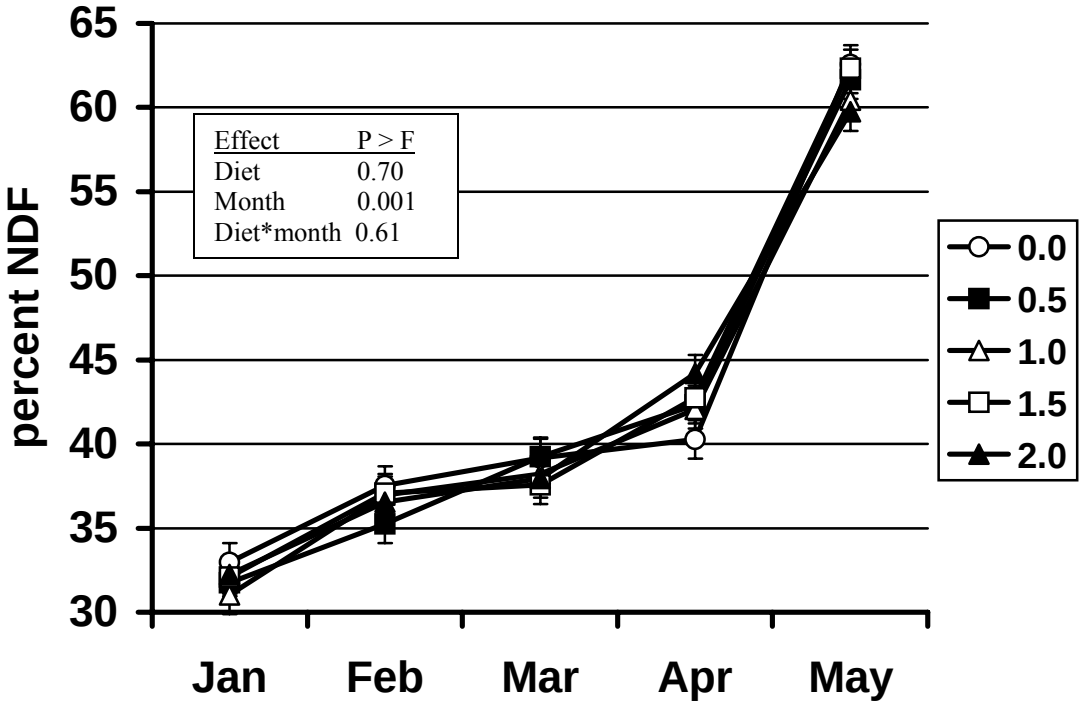


Figure 4: Least squares means for percent acid detergent fiber (ADF) of samples from ryegrass paddocks grazed by steers receiving various levels of corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), or 2.0% (2.0) of bodyweight.

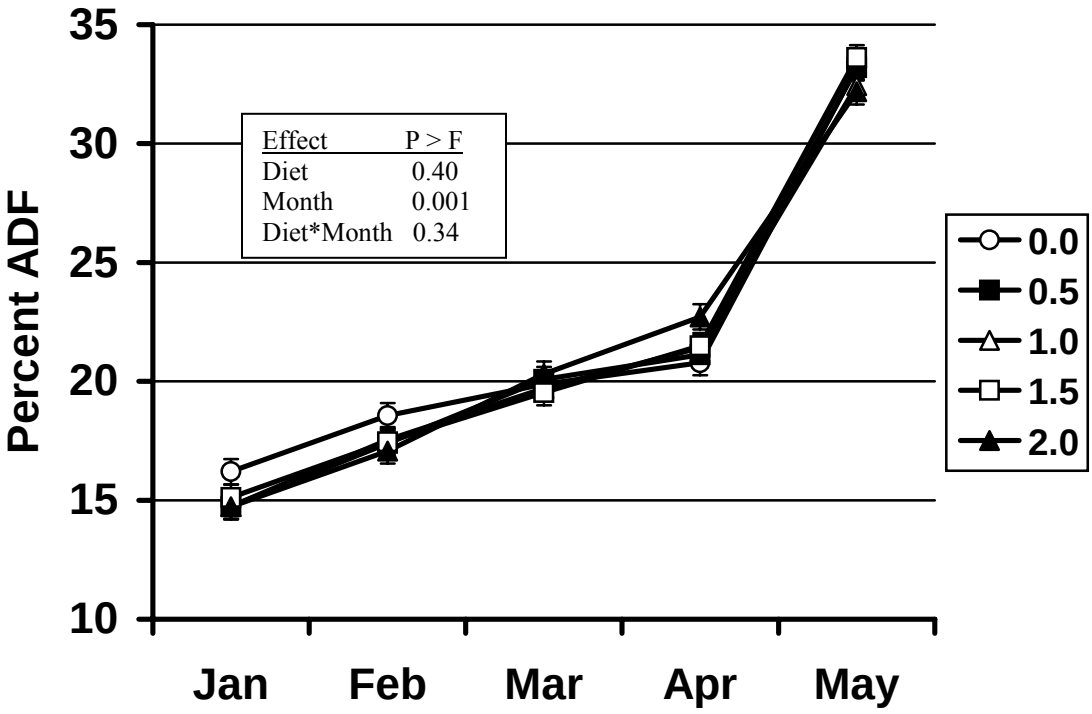
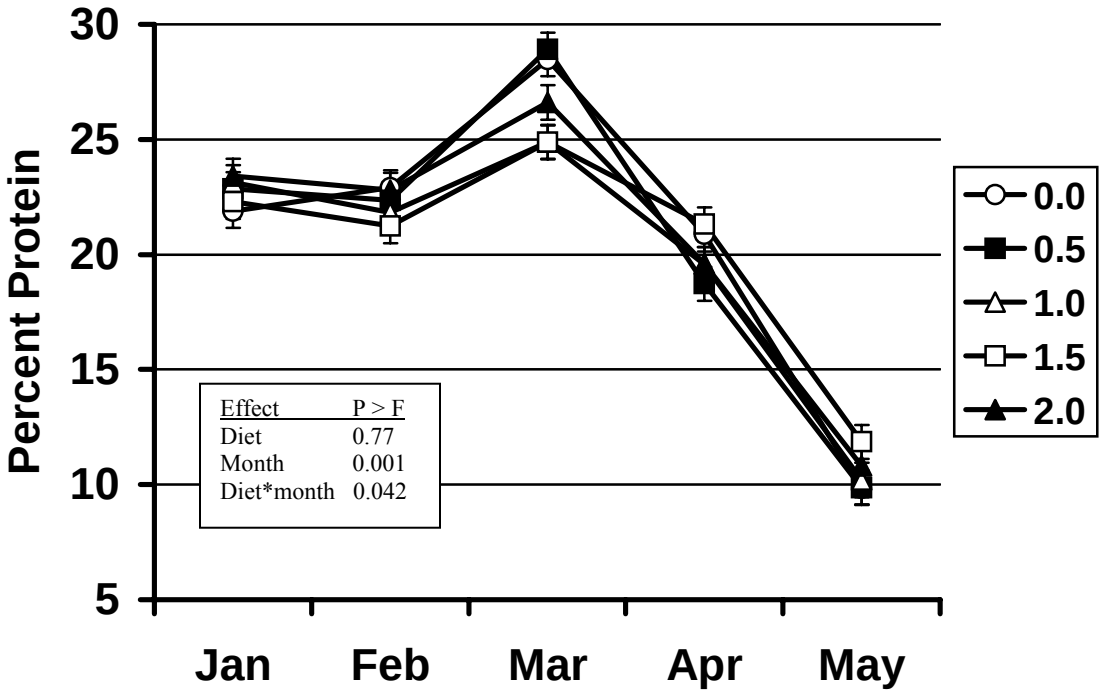


Figure 5: Least squares means for percent protein of samples from ryegrass paddocks grazed by steers receiving various levels of corn supplemented at 0% (0.0), 0.5% (0.5), 1.0% (1.0), 1.5% (1.5), or 2.0% (2.0) of bodyweight.



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APPENDICES

APPENDIX A.

PROXIMATE ANALYSIS OF LONGISSIMUS MUSCLE

A. Safety Precautions
   a. Use precaution when inserting or removing items from ashing oven. Use tongs when handling crucibles
   b. Ensure that exhaust tube is under fume hood and hood is properly working before ashing.

B. Apparatus
   a. *Moisture and Fat Analyzer* – SMART Trac™ Rapid Moisture/Fat Analyzer
   b. *Ashing Oven* – Phoenix™ microwave-powered muffle furnaces
   c. *Crucibles* – CEM quartz fiber crucibles
   d. *Sample Pads* – 4 x 4 in square CEM sample pads
   e. *Film and Tubes* – CEM Trac fat analyzer film and tubes
   f. *Blender* - Waring™ two-speed laboratory blender with 1 qt. stainless steel container.
   g. *Balance* - Fisher accu series II™ Analytical Balance or comparable model with 0.0001g sensitivity.

C. Procedures
   a. Sample Preparation
      i. Remove all excess fat, muscle, and or connective tissue from meat sample. Cut or separate sample into smaller pieces for grinding or blending.
      ii. Place meat sample in blender a little at a time and mix and blend sample until a consistent paste like substance is achieved. There should be no remaining chunks at the end of blending. Remove the contents from the blender container using a spatula or plastic scoop and place in labeled sample bag.
      iii. Sample can be analyzed at this point or places in refrigerator for analyzes within 24 h.

   b. Moisture and Fat Analyzes
      i. Select procedure from SMART Trac computer. I the case of a new material consult CEM personnel to program new procedure.
      ii. Place two sample pads on moisture analyzer balance and tare. Enter sample identification
      iii. Remove pads from moisture analyzer and evenly spread 3.5 – 4.0 g of meat sample on one of the pads. Place the other sample pad on top of the pad containing the meat sample and sandwich the two pads together
      iv. Place the sample and pad back on the moisture analyzer balance and latch lid. It will take approximately 4 –5 m to compute moisture percentage.
      v. Following moisture analyzes, place dried sample pad on one sheet of film. Fold the film over the sample pad by folding opposing sides of the pad into

the middle. Then fold one of the open ends into the middle. The next step is to tightly roll the film and sample pad so that all of the sample pad and sample is encompassed by the film

vi. The rolled film and pad is now placed in a plastic fat analyzer tube. Use sample compressor to shove the sample to bottom of the tube. Pound the sample with the compressor two or three times to firmly compress the sample.

vii. Place tube in fat analyzer chamber and follow computer instructions to start fat analyzes. Analyzes takes approximately 1 m. *WARNING: Leave sample in fat analyzer chamber until next sample analyzes to prevent equipment damage.*

viii. Following fat analyzes SMART Trac computer will print out moisture and fat analyzes data for sample.

ix. When desired replicate sample procedure.

c. Ashing

i. Weigh crucible and two crucible covers (W_1) on analytical balance and record.

ii. Place on of the covers in the bottom of the crucible and weigh approximately 5g of blended sample into the crucible. Place the other cover on top of the sample and weigh (W_2). Note: All weights should be recorded to 0.0001g.

iii. Place crucible in muffle furnace using tongs and select ashing program. Ash for 25 to 30 m at 550°C.

iv. Remove crucible from ashing oven using tongs. *WARNING: Oven and crucibles are extremely hot; use precaution.*

v. Allow samples to cool for approximately 2 m and weigh crucible on balance. Be sure crucibles are at a constant weight before recording weight (W_3).

vi. When desired replicate sample procedure.

d. Calculations

i. Calculate all components on a percentage basis.

ii. Ash

a. $((W_3 - W_1)/(W_2 - W_1)) * 100$

iii. Protein (P) – Subtract average moisture (M), fat (F), and ash (A) percentages from 100 for individual samples.

a. $P = 100 - M - F - A$

APPENDIX B.

METHOD FOR DETERMINING NEUTRAL DETERGENT FIGER

A. Reagents

a. *Neutral Detergent Solution (NDS)* – Add 30 g sodium laryl sulfate, USP; 18.61 g Ethylenediaminetetraacetic Disodium Salt, Dihydrate; 6.81 g sodium tetraborate decahydrate; 4.56 g sodium phosphate dibasic, anhydrous; and 10.0 ml triethylene glycol, in 1 L distilled H_2O. Agitate and heat to aid solution. Check pH range to 6.9 to 7.1.
b. *Alpha-amylase* – Heat-stable bacterial alpha-amylase: activity + 340,000 Modified Wohlgemuth Units / ml (ANKOM Technology #FAA). One modified uohlgemuth unit is that activity which will dextrinize 1.0 mg of soluble starch to a defined size dextrin in 30 minutes.
c. *Sodium sulfite* – Na_2SO_3, anhydrous
d. *Acetone* – Use grade that is free from color and leaves no residue upon evaporation.

B. Safety Precautions

a. Acetone is highly flammable. Use fume hood when handling acetone and avoid inhaling or contact with skin. Make sure bags are completely dry and that all the acetone has evaporated before placing in oven.
b. Sodium laryl sulfate will irritate the mucus membranes. A dusk mask and gloves should be worn when handling chemical.

C. Apparatus

a. *Digestion Apparatus* – ANKOM$^{200/220}$ Fiber Analyzer
b. *Filtration device* – ANKOM Technology F57 Filter Bags
c. *Heat Sealer* – Requires high enough temperature to melt and seal polymer in filter bags
d. Desiccator

D. Procedure

a. Prepare Sample
   i. Weigh filter bag (W1) and zero balance.
   ii. Weigh 0.5 g (±0.05 g) of air-dried sample (W2), ground to pass through a 1-mm screen, directly into filter bag. Weigh one blank bag and include in digestion to determine blank bag correction (C1)
   iii. Seal the bags closed within 1-cm from the open edge using the heat sealer.
   iv. Spread sample uniformly inside the filter bag by shaking and lightly flicking the bag to eliminate clumping
   v. A maximum of 24 bags may be placed in the suspender. All nine baskets are used regardless of the number of bags being processed. Place three bags per basket and then stack baskets on center post with each basket rotated 120 degrees. The weight is placed on top of the empty 9th basket to keep basket to keep the bag suspender submerged.

b. When processing 20-24 sample bags add 2000 ml of ambient Neutral Detergent Solution (NDS) into digestion vessel. If processing less than 20 bags add 100 ml/bag of detergent solution (minimum of 1500 ml). Add 20 g (0.5 g/50 ml of NDS) of sodium sulfite to the solution in the vessel and 4.0 ml of heat stable alpha-amylase during digestion.
c. Place bag suspender with samples into the solution in digestion vessel. Turn agitate and heat on and begin timing for 60 minutes. Close and seal lid of digestion vessel.
d. After 60 minutes have elapsed turn agitate and heat off, open the valve and exhaust hot solution before opening lid**.** *WARNING: The solution in vessel is under pressure. The valve should be opened first to remove pressure before lid can be opened. Ensure exhaust hose is securely positioned for safe disposal of effluent.*
e. After the solution has been exhausted close valve and open the lid. Add approximately 2000 ml of hot (90-100º C) H_2O and 4.0 ml of alpha-amylase to the first and second rinses. Lower lid but do not tighten. Turn agitate on and leave heat off for 5 minutes. Exhaust water and repeat rinse a total of three times.
f. Remove filter bags from bag suspender and gently press out excess water. Place in beaker and soak in acetone. Allow bags to soak 5 minutes then remove and lightly press out excess acetone.
g. Spread bags out and let air dry. Complete drying in oven at 105º C for 4 hours. Longer drying period may be required depending on oven and frequency of sample introduction into the oven. Remove bags from oven, place directly into desiccator. Cool to ambient temperature and weigh bags (W3).
h. Calculate percent NDF on dry basis: % NDF = 100 (W3 – (W1 x C1)) / W2

    i. Where: W1 = Bag tare weight
        1. W2 = Sample weight, expressed on a dry basis
        2. W3 = Final bag and fiber weight
        3. C1 = Blank bag correction (final oven-dried weight / original blank bag weight)

APPENDIX C.

METHOD FOR DETERMING ACID DETERGENT FIBER

A. Reagents

a. *Acid Detergent Solution (ADS)* – Add 20 g cetyl trimethylammonium bromide (CTAB) to 1 L 1.00*N* H_2SO_4 previously standardized. Agitate and heat to aid solution.
b. *Acetone* – Use grade that is free from color and leaves no residue upon evaporation.

B. Safety Precautions

a. Acetone is highly flammable. Use fume hood when handling acetone and avoid inhaling or contact with skin. Make sure bags are completely dry and that all the acetone has evaporated before placing in oven.
b. Rubber gloves and face shield should be worn when handling sulfuric acid. Always add sulfuric acid to water. If acid contacts skin wash with copious amounts of water.
c. CTAB will irritate the mucus membranes. A dusk mask and gloves should be worn when handling chemical.

C. Apparatus

a. *Digestion Apparatus* – ANKOM$^{200/220}$ Fiber Analyzer
b. *Filtration device* – ANKOM Technology F57 Filter Bags
c. *Heat Sealer* – Requires high enough temperature to melt and seal polymer in filter bags
d. Desiccator

D. Procedure

a. Prepare Sample – *Alternative method* – use weighed sample bags from NDF determination (if this methods used proceed to step v.)
   i. Weigh filter bag (W1) and zero balance.
   ii. Weigh 0.5 g (±0.05 g) of air-dried sample (W2), ground to pass through a 1-mm screen, directly into filter bag. Weigh one blank bag and include in digestion to determine blank bag correction (C1)
   iii. Seal the bags closed within 1-cm from the open edge using the heat sealer.
   iv. Spread sample uniformly inside the filter bag by shaking and lightly flicking the bag to eliminate clumping.
   v. A maximum of 24 bags may be placed in the suspender. All nine baskets are used regardless of the number of bags being processed. Place three bags per basket and then stack baskets on center post with each basket rotated 120

degrees. The weight is placed on top of the empty 9th basket to keep basket to keep the bag suspender submerged.

b. When processing 20-24 sample bags add 2000 ml of ambient Acid Detergent Solution (ADS) into digestion vessel. If processing less than 20 bags add 100 ml/bag of detergent solution (minimum of 1500 ml).
c. Place bag suspender with samples into the solution in digestion vessel. Turn agitate and heat on and begin timing for 60 minutes. Close and seal lid of digestion vessel.
d. After 60 minutes have elapsed turn agitate and heat off, open the valve and exhaust hot solution before opening lid**.** *WARNING: The solution in vessel is under pressure. The valve should be opened first to remove pressure before lid can be opened. Ensure exhaust hose is securely positioned for safe disposal of effluent.*
e. After the solution has been exhausted close valve and open the lid. Add approximately 2000 ml of hot (90-100º C) H_2O and lower lid but do not tighten. Turn agitate on and leave heat off for 5 minutes. Exhaust water and repeat rinse a total of three times.
f. Remove filter bags from bag suspender and gently press out excess water. Place in beaker and soak in acetone. Allow bags to soak 5 minutes then remove and lightly press out excess acetone.
g. Spread bags out and let air dry. Complete drying in oven at 105º C for 4 hours. Longer drying period may be required depending on oven and frequency of sample introduction into the oven. Remove bags from oven, place directly into desiccator. Cool to ambient temperature and weigh bags (W3).
h. Calculate percent ADF on dry basis: % ADF = 100 (W3 – (W1 x C1)) / W2

    i. Where: W1 = Bag tare weight
        1. W2 = Sample weight, expressed on a dry basis
        2. W3 = Final bag and fiber weight
        3. C1 = Blank bag correction (final oven-dried weight / original blank bag weight)

APPENDIX D.

SENSORY PANEL SAMPLE SHEET

Name_____ Date_____ Project_____

Sample #	Initial Juiciness	Sustained Juiciness	Initial Tenderness	Sustained Tenderness	Flavor Intensity	Beef Flavor

Juiciness	Tenderness	Flavor Intensity	Beef Flavor
8=Extremely Juicy	8=Extremely Tender	8=Extremely Intense	8=Extremely Characteristic
7=Very Juicy	7=Very Tender	7=Very Intense	7=Very Characteristic
6=Moderately Juicy	6=Moderately Tender	6=Moderately Intense	6=Moderately Characteristic
5=Slightly Juicy	5=Slightly Tender	5=Slightly Intense	5=Slightly Characteristic
4=Slightly Dry	4=Slightly Tough	4=Slightly Bland	4=Slightly Uncharacteristic
3=Moderately Dry	3=Moderately Tough	3=Moderately Bland	3=Moderately Uncharacteristic
2=Very Dry	2=Very Tough	2=Very Bland	2=Very Uncharacteristic
1=Extremely Dry	1=Extremely Tough	1=Extremely Bland	1=Extremely Uncharacteristic