To the Graduate Council:

I am submitting herewith a thesis written by Fred William Pohlman entitled "The Effects of Different Backgrounding Pastures and Length of Grain Finishing Period on Carcass, Chemical and Sensory Characteristics of Beef from Angus, Hereford and Crossbred Steers." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

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THE EFFECTS OF DIFFERENT BACKGROUNDING PASTURES AND LENGTH OF GRAIN FINISHING PERIOD ON CARCASS, CHEMICAL AND SENSORY CHARACTERISTICS OF BEEF FROM ANGUS, HEREFORD AND CROSSBRED STEERS

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Fred William Pohlman
May 1990

ACKNOWLEDGMENTS

The author wishes to express his gratitude and appreciation to the following for making this thesis possible.

To Dr. M. James Riemann and Dr. William R. Backus for their hours spent, encouragement and guidance throughout my graduate program.

To Dr. H. Dwight Loveday for his assistance on the graduate project and serving on the author's graduate committee.

To Dr. Marjorie Penfield for her assistance in conducting sensory panels and for her advice during statistical analysis.

To Mr. Bob Grindstaff, William Barron, Steve Edwards, Doug Mitchell, Thomas Powell, and Bob Schell for their friendship and assistance in carcass data collection, fabrication and laboratory procedures. A special thanks is extended to Mr. Grindstaff, William Barron and Doug Mitchell.

To Nancy Austin for her assistance in manuscript preparation.

To Tami Glover for her patience and assistance in data collection and analysis.

A special thanks to Mr. Craig Bacon for his long hours, dedicated friendship, and assistance in fabrication, laboratory analysis and his advice during statistical analysis.

Finally, the author wishes to express his deepest gratitude to his parents, Mr. and Mrs. Delmar Pohlman, for their continuing support and encouragement.

ABSTRACT

Angus, Hereford, Angus X Hereford and crossbred steers were used to determine the effect of grain feeding time (DOF) and pasture type on carcass traits and sensory, chemical and physical characteristics of the longissimus muscle. The steers were backgrounded for 8 mo. on either ryegrass (n=18), orchardgrass (n=18), Kentucky 31 Fescue (n=18) or fescue-clover mixed (n=32) pasture. They were placed in a drylot in July and August, fed whole shelled corn, and serially slaughtered. Steers from the ryegrass, orchardgrass, Kentucky 31 Fescue and fescue-clover mixed pasture all had grain feeding periods of 0, 56, and 112 DOF. The steers from the fescue-clover mixed pasture had additional DOF increments of 28, 84 and 140.

Carcass weights increased linearly from 191.7 kg (0 DOF) to 300.6 kg (112 DOF). Adjusted fat thickness also increased ($P<.05$) linearly from 4.3 mm (0 DOF) to 11.4 mm (112 DOF). The least square mean quality grade and yield grade for the 0, 56 and 112 DOF steers were high Standard, 1.8; average Select, 2.1; and low Choice 2.8, respectively. The least square mean quality and yield grade for the steers from the ryegrass, Kentucky 31 Fescue, orchardgrass, and fescue-clover mixed pastures were low Select, 2.25; low Select, 2.21, average Select, 2.61; and low Select, 1.96, respectively.

The 0 DOF steers had less ($P<.05$) lipid (2.57%) and more ($P<.05$) moisture (75.42%) in the uncooked longissimus muscle than the 56 or 112 DOF groups. The 0 DOF cattle had more ($P<.05$) soluble collagen (2.93 mg/g) than the 56 DOF (2.64 mg/g) or the 112 DOF (1.86 mg/g) steers. There was

no difference (P>.05) in total collagen for any of the DOF groups. Pasture type had no effect (P>.05) on soluble collagen or total collagen.

Flavor of the loin steaks changed (P<.05) from 0 DOF (slight milky-oily) to 56 DOF (slight beef fat flavor), but did not change (P>.05)from 56 to 112 DOF. Steaks became juicier, more tender, and higher in acceptability (P<.05) as DOF increased from 0 to 112 DOF. Pasture type had no affect (P>.05) on any of the sensory parameters of flavor, juiciness, tenderness or overall acceptability.

The fescue-clover backgrounded steers were fed in drylot for up to 140 DOF. Quality grade improved (P<.05) from 0 DOF (low standard) up to 140 DOF (high good). Numerical yield grade increased (P<.05) from 0 DOF (1.4) up to 140 DOF (2.6). Wholesale cut weights also increased with increasing DOF. There was no difference (P>.05) in total collagen content across DOF. Sensory panel evaluated tenderness, juiciness and overall acceptability scores tended to improve up to 140 DOF.

Warner-Bratzler shear force values were obtained for medial, center and lateral sections of the loin steaks. Warner-Bratzler shear force data from the 0, 56 and 112 DOF cattle were pooled. Shear force values for the cores taken from the center of the steaks were lower (P<.05) than shear force values for cores taken from the medial and lateral sections.

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CHAPTER I

INTRODUCTION

The cattle industry has changed dramatically over the past 20 to 30 years. Cattle producers have recognized the need for faster growing, later maturing cattle, and have therefore shifted away from the earlier maturing cattle of the 1950's.

Producers have realized the need to utilize as much non-tillable land as possible for animal production. This has caused them to look at pasture alternatives that will remain productive over the winter months, and sustain live weight gains in cattle. It is also important to produce carcasses that will grade a minimum USDA quality grade of low Choice, and maximum USDA yield grade of 2.

Consumers have also become more health conscious in the past decade. They have demanded that beef contain less fat, and yet be tender, juicy and flavorful. Cattle producers understand that consumers tend to discriminate against beef from grass-finished steers. Consumers rate grass-finished beef less desirable in flavor, juiciness, tenderness and overall acceptability than grain-finished steers.

Therefore, the objective of this study was to determine the effects of pasture type and length of grain feeding on carcass traits, sensory attributes and chemical composition of longissimus muscle from steers.

CHAPTER II

REVIEW OF LITERATURE

I. FEEDING REGIMENS AS THEY AFFECT CARCASS, CHEMICAL, PHYSICAL AND SENSORY CHARACTERISTICS

In the 1950's cheap grain was used to finish cattle in feedlots. Because the demand for beef is expected to remain high, the fluctuating grain market of more recent years dictates that other feedstuffs (primarily forage) be considered as an alternative for growing and finishing.

Increased grain prices have decreased the profits for cattle feeders who grain finish cattle for market. Therefore, to produce beef more economically, utilization of forage feeding systems must be considered. These systems may include finishing on grass only, backgrounding on grass and finishing in drylot for different lengths of time, or feeding concentrate supplemented with roughage in drylot (Harrison et al., 1978).

Finishing beef on forage in the United States is rarely done. This is because grass-finished beef has less desirable flavor than beef from cattle finished on grain. Melton et al. (1982a,b) reported that muscle from limited grain-fed and grain-fed steers had superior flavor scores than muscle from grass-fed steers. Bowling et al. (1977), Harrison et al. (1978), Westerling and Hedrick (1979), Brown et al. (1979), and Schroeder et al., (1980) also found that flavor desirability increased as cattle were fed grain longer.

There are several reasons suggested for this undesirable flavor: (1) grass-fed carcasses tend to be lower in fat content as reported by Leander et al., (1978), Bowling et al. (1977), Moody, (1976), and Harrison et al., (1978); (2) grain-fed cattle produce heavier and superior quality grading carcasses than grass-fed cattle (Dinius and Cross, 1978), and (3) the fatty acid composition of grass-fed beef tends to be different from that of grain-fattened beef (Westerling and Hedrick, 1979; Brown et al., 1979; Melton et al., 1982a). The fatty acid composition of grass-fed beef has been reported to cause muscle to have a "dairy" or "milky-oily" flavor (Melton et al., 1982b) or "grassy" flavor (Schroeder et al., 1980). This change in fatty acid composition has been implicated in contributing to desirable beef flavor.

There are other reasons why beef cattle are generally not finished on forage. Packers tend to discriminate against forage-finished beef due to inferior carcass quality grades and dressing percentages (Dinius and Cross, 1978; Hedrick et al., 1983; Schroeder et al., 1980), and higher cooler shrinkage of carcasses from grass-fattened cattle (Hedrick et al., 1983; Schroeder et al., 1980; Tatum et al., 1980), eventhough carcasses from grass-finished cattle have superior yield grades (Tatum et al., 1980). Also, grass-finished cattle gain weight (up to .1 kg/d) slower than grain-finished cattle (Clanton, 1977; Prior et al., 1977; Lake et al., 1974; Smith et al., 1977)

Consumers discriminate against grass-finished beef because of lean color differences and external fat color differences from grain finished beef (Craig et al., 1959) and because of differences in sensory characteristics between grass- and grain-finished beef (Hedrick et al., 1983; Dinius and Cross, 1978; Bowling et al., 1977; Schupp et al., 1976).

Harrison et al. (1978) wintered 38 head of crossbred calves on corn silage, alfalfa haylage, cracked corn and supplement for 134 days before grazing on bromegrass and bluestem pasture for 133 days. Upon completion of grazing, 10 steers were slaughtered. The remaining 28 steers were randomly assigned to either a short-term, long-term, or forage-fed finishing program. Increasing the level of nutrition and time on feed improved marbling score and carcass quality parameters. Zinn et al. (1962) and Dinius and Cross (1978) reported similar results. Also, nutritional regimen had no effect ($P>.05$) on lean maturity scores (color). Lean texture of the longissimus muscle did not differ ($P>.05$) among treatments; however, it was noted that lean texture tended to be finer in longer fed cattle. Actual and adjusted fat thickness were lower ($P<.05$), and ribeye area smaller ($P<.05$) for carcasses from grass-fed and short-fed cattle. Long- and forage-fed cattle deposited more subcutaneous fat than the grass- and short-fed steers. Carcasses from grass-fed cattle had smaller ($P<.05$) ribeye areas than short- and long-fed cattle, but did not differ from carcasses of forage-fed cattle. USDA yield grades were not different ($P>.05$) between carcasses from forage- and long-fed cattle or between carcasses from grass- and short-fed cattle. Utley, Hellwig and McCormick (1975) also found that grass- and short-fed cattle produced similar yield grading carcasses as did forage- and long-fed cattle. Grain-fed beef carcasses were inferior in yield grade because the carcasses had a higher kidney, pelvic and heart fat percentage which increased with length of feeding. It was also observed that carcass weights increased ($P<.05$) with length of feeding.

Harrison et al. (1978) found that palatability scores were superior for cattle fed the longest time on feed and the highest nutritional level. Also, grass-fed beef was less tender from trimmer carcasses than from fatter carcasses, which was contributed to greater cold shortening. These results are in agreement with Wanderstock and Miller (1948); Reddish (1956); Kropf et al. (1975); and Bowling et al. (1977). Harrison et al. (1978) also found that tenderness of the longissimus dorsi was not different from carcasses finished to the same fat thickness or similar yield grades. Bull et al. (1941), Hunt et al. (1953), Huffman (1974) and Schupp et al. (1976) also reported that muscle from carcasses of similar yield grades were not different ($P>.05$) in tenderness as rated by a sensory panel. Loin steaks from the longer fed cattle were more desirable in flavor, and juicier than the grass fed beef ($P<.05$). This is in agreement with Reddish (1956), Meyer et al. (1960), Oltjen et al. (1971) and Kropf et al. (1975) who also found that flavor, as well as tenderness and overall desirability of longissimus steaks improves in higher grading cattle. Warner-Bratzler shear force of the longissimus muscle did not differ among nutritional regimens. This is in agreement with Meyer et al. (1960) but in disagreement with Kropf et al., (1975) and Bowling et al. (1977) who concluded that steaks from grain-fed cattle yield lower shear force values than steaks from grass-fed cattle. In contrast, Huffman (1974) found that steaks from cattle finished on grain for 90 days were slightly tougher by Warner-Bratzler shear than those from cattle finished on grass.

In another study, Dinius and Cross (1978) experimented with 40 head of Hereford steers. The steers were fed either ground alfalfa hay or an 85% concentrate diet for 3, 6 or 9 weeks. Cold carcass weight increased linearly with days on feed. Steers on the higher plane of nutrition had greater daily carcass gain ($P<.05$) than steers fed hay. Daily carcass gain increased ($P<.05$) with increasing length of concentrate feeding. Carcasses from steers fed hay had greater cooler shrinkage (P<.01) than carcasses from steers fed concentrate the longest. Also, dressing percentage increased (P<.05) with length of concentrate feeding. This is in agreement with Zinn et al. (1962) who discovered that steers fed all-forage diets have lower dressing percentages and higher cooler shrinkage than grain-fed steers.

Dinius and Cross (1978) also found that days on feed did not affect (P>.05) lean color, texture or firmness. This agrees with the findings of Reagan et al. (1977) and disagrees with Zinn et al. (1962). Dinius and Cross (1978) also reported that USDA quality grade, fat deposition and USDA yield grade increased (P<.05) with length of feeding. Length of time that concentrate was fed influenced carcass composition, but little difference (P>.05) was observed in palatability (tenderness, juiciness, and connective tissue rating) or cooking yields (total cooking loss). In a similar study performed by Bowling et al. (1977), no difference (P>.05) in juiciness or cooking loss was found between forage-fed and grain fed steers. But, Bowling et al. (1977) found that steaks from grain-fed steers had had less (P<.05) connective tissue and greater (P<.05) overall palatability than steaks from grass-fed steers.

Bowling et al. (1977) also examined carcass characteristics of forage finished and grain-finished beef. They selected grain-finished carcasses to have the same (± 10%) USDA skeletal maturity score as the forage-finished carcasses, resulting in 30 pairs of carcasses. Hot carcass weight (HCW), USDA yield grade and USDA quality parameters did not statistically differ between the forage-finished and the grain finished steers. External fat thickness was less for the forage-finished (4.1 mm) than for the grain-finished steers (8.4 mm). The grain finished steers were more variable in fat thickness (2.5 - 15.2 mm) compared to the forage-finished steers (2.0 - 9.6 mm). Ribeye area was larger for the grain finished steers than the forage-finished steers ($P<.05$). The grain finished steers had an average of 10 cm^2 larger longissimus muscle area than the forage finished calves. Percentage kidney, pelvic and heart fat was also greater for the grain finished steers than for the forage-finished steers.

Bowling et al. (1977) examined USDA conformation scores of forage-finished and grain-finished steers. Conformation scores were used to evaluate the overall muscling of the beef carcasses. Conformation scores of the carcasses ranged from high Good for the forage-finished steers to low Choice for the grain finished steers. Cooking characteristics and sensory panel evaluations were also determined. They found that beef from grain-finished versus forage-finished steers were not different ($P>.05$) in selected cooking and sensory characteristics (cooking loss, cooking time, degree of doneness, initial juiciness, sustained juiciness or flavor intensity). Panelists discovered that forage-finished beef was ($P<.05$) less desirable in flavor scores and overall acceptability than grain-finished beef. This agrees with reports by Wanderstock and Miller (1948); Wheeling et al. (1975); Cross and Smith (1976); Kropf et al. (1975). Marbling score was not statistically different between the grain-finished and forage-finished steers, differences in flavor was not attributed to differences in marbling.

Tatum et al. (1980) studied the effects of time on feed compared to carcass characteristics and cooked beef palatability. Steers were fed for 100, 130 or 160 days, and then slaughtered. Palatability of the steaks tended to increase with marbling score. However, increases in marbling score increments were not always statistically related to the differences in palatability scores. Campion et al. (1975) reported similar results. Steaks from carcasses grading high Choice and average Choice were ($P<.05$) juicier, superior in flavor and more palatable than were steaks from the lower grading carcasses (low Good and high Standard). But, panelists concluded that steaks from low Choice, high Good and average Good carcasses were not different in juiciness, tenderness and overall palatability. Increased feeding time from 100 days to 160 days improved flavor desirability ratings but did not significantly affect juiciness, tenderness and overall palatability ratings. Zinn et al. (1970a) reported conflicting results. They found that tenderness scores increased with time on feed among cattle fed for periods up to 180 days.

Tatum et al. (1980) also discovered that increased time on feed resulted in an associated increased carcass maturity, increased fat deposition, increased (higher numerical) yield grade and increased incidence of carcasses receiving the Choice grade. Fat thickness and marbling scores were highly variable between carcasses, while carcass conformation, longissimus dorsi area, estimated kidney, pelvic and heart fat percentage, and yield grade were moderately variable.

Other researchers reported that increasing length of feeding prior to slaughter, increases degree of marbling and quality grades (Wellington, 1968; Zinn et al., 1970a; Campion et al., 1975), external fat thickness (Campion et al., 1975), and improved tenderness (Zinn et al., 1970b; Epley et al.,1968).

Tatum et al. (1980) also reported the coefficient of variation among palatability attributes ranged from low to moderate for myofibrillar tenderness rating (13.6), overall tenderness rating (13.0) and overall palatability rating (12.0). Shear force (21.2) and juiciness (15.3) were most variable, while connective tissue amount (6.8) and flavor desirability (8.8) were least variable. Sensory panel ratings for tenderness generally improved while shear force values decreased as degree of marbling increased. Steaks with marbling scores of "modest" had lower ($P<.05$) shear force values and received higher ($P<.05$) ratings for overall tenderness, flavor desirability and overall palatability than steaks with marbling scores of "slight-minus" or "traces-plus." Similar findings were reported by Jennings et al. (1978). Steaks from low Select to high Choice carcasses exhibited similar palatability attributes. Steaks from carcasses grading average Choice and above were more juicy and more desirable in flavor and had lower shear force values than steaks from carcasses grading high Good or lower. Similar findings were reported by Cover et al. (1956), Doty and Pierce (1961) and McBee and Wiles (1967) who found that steaks from higher grading beef carcasses were more desirable in overall palatability than those from lower grading carcasses.

Hedrick et al. (1983) placed 351 Hereford-Angus crossbred steers on four different production systems consisting of 13 dietary treatments. They found that grass-finished animals had lower carcass quality grades, superior cutting yields and darker colored longissimus muscle ($P<.05$) than that of carcasses from other treatments. Loin steaks from the grass-fed calves had inferior flavor, juiciness, tenderness and overall acceptability scores ($P<.05$), while top round roasts were evaluated to be less desirable in flavor and overall acceptability ($P<.05$) than similar cuts from the other dietary treatments. Nutritional regimen had little effect on any other sensory characteristics or shear values for steaks and top round roasts although, steaks from the grass-fed treatments had larger ($P<.05$) Warner-Bratzler shear force values than all other treatments. Sensory panel tenderness scores and Warner-Bratzler shear force values were not affected by increasing quality grade. Parrish (1974) found that higher quality grading carcasses do not always have improved tenderness. Little difference in shear value between high Good and low Choice carcasses for the longissimus muscle has been observed. Epley et al. (1968) found that flavor desirability and Warner-Bratzler shear values were not affected when cattle were fed for longer than 139 days.

Aberle et al. (1981) contends that growth rate of the animal prior to slaughter may be a more important determinant of meat tenderness than the length of time concentrate is fed. Hedrick et al. (1983) discovered that forage-fed animals gained weight slower and yielded tougher meat. Therefore, they concluded that the interaction between age of the animal, rate of gain prior to slaughter and period of continuous grain feeding affected tenderness.

Epley et al. (1968) studied the influence of sire and length of feeding on palatability of beef steaks. It was found that subcutaneous fat thickness increased with time on feed. This was not, however, associated with improved sensory characteristics of steaks and roasts compared to the shorter fed cattle. Forage-fed calves had lower ($P<.05$) dressing percentages than the grain-fed animals. As the steers were fed longer, dressing percentages improved ($P<.05$). Carcasses from the straight fescue-fed animals quality graded slightly lower than carcasses from fescue-legume mixed pastures. Bowling et al. (1978); Harrison et al. (1978); Leander et al. (1978); Skelly et al. (1978); Young and Kauffman (1978);

Schroeder et al. (1980); and Bidner et al. (1981) all found that grain-finished animals produced superior quality grading carcasses, with more external fat, that resulted in inferior cutting yields than grass-fed animals. Epley et al. (1968) also examined cooking losses of steaks and roasts. He found that total cooking losses were greater for the steaks from fatter carcasses than for steaks from trimmer carcasses.

Jacobson and Fenton (1956) determined the effects of three feeding levels upon palatability and nutritive value of beef. They studied the influence of animal age upon palatability factors. Three muscles (longissimus dorsi, psoas major, and semimembranosus with adductor) were studied from 24 heifer carcasses. There were three nutritional levels (low, medium and high) for each age (32, 48, 64, and 80 weeks). Fat content increased with feeding level for each of the three kinds of muscles ($P<.01$). An increase in age resulted in increased fat content. Fat percentage and moisture percentage were inversely related in all three muscles. There was much variability in shear force values for cores from adjacent parts of the same muscle and also between muscles from animals on the same feeding regimen. Shear force values were not associated with the level of nutrition. Age of the animal up to 80 weeks had no effect on shear force. Level of nutrition affected flavor ($P<.05$). The two higher planes of nutrition treatments were superior in flavor to the low level. The higher level of nutrition groups were more tender (for the longissimus dorsi) as evaluated by sensory panel than from those on the low level. No differences in tenderness ratings for the other muscles was attributed to the level of feeding.

Prior et al. (1977) studied two types of cattle (Angus-Hereford crossbreds, small type; and 3/4 or 7/8 Charolais and Chianina X Hereford or Chianina X Angus crossbreds, large type) for their response to different dietary energy densities. Average daily gain increased ($P<.05$) with energy intake in both types of cattle. When carcasses were adjusted to a constant carcass weight, increasing dietary energy intake improved degree of marbling and quality grade. Increasing dietary energy also increased fat thickness over the 12th rib, kidney and pelvic fat percentage and yield grade in small type cattle but not in large type cattle. Moisture decreased and fat increased in the rib sections of both the large and the small type cattle as a result of increased dietary energy intake ($P<.05$).

Adams et al. (1973), Cole et al. (1964), Hedrick et al. (1970), Koch et al. (1976), Koch et al. (1979), and Smith et al. (1976) examined exotic breeds of cattle for the rate and efficiency of growth and carcass merit. They found that rate of growth, feed efficiency and carcass composition was related to breed type, while little variation due to breed type was associated with palatability attributes.

Prior et al. (1977) also found that large framed cattle at 403.5 kg carcass weight had a superior dressing percentage, larger longissimus muscle area, less fat over the 12th rib and superior yield grade than small framed cattle at 319.3 kg carcass weight. In small framed cattle, quality grade, adjusted fat thickness, percentage of kidney and pelvic fat and yield grade increased as energy intake increased. The small framed cattle tended to deposit fat quicker than the large type cattle when fed the medium and high energy rations. This is in contrast to Guenther et al. (1965) and Jesse et al. (1976) who did not find a difference in composition of gain of carcasses evaluated at constant weights from Hereford steers fed varying levels of energy. Increasing dietary energy intake also appeared to increase the rate of weight gain nearly as much in large type cattle as in small type cattle. Energy level fed had little effect on Warner-Bratzler shear force or on flavor, juiciness, tenderness, or overall acceptability.

Schroeder et al. (1980) placed 35 Hereford yearling steers on five different management feeding systems and three pasture combinations. Following a four month grazing period, 19 head were slaughtered and 16 were given an additional grain-finishing period of 104 days on an 80% concentrate diet prior to slaughter. Ribeye area and lean quality parameters improved with days on feed. No differences ($P>.05$) were observed for overall maturity score. Carcasses from the all-forage diets were found to possess darker ribeye muscles ($P<.05$). Forage-finished cattle also produced carcasses that had greater ($P<.05$) percentage cutability. However, this advantage was diminished by their lower ($P<.05$) dressing percentages and increased ($P<.05$) cooler shrinkage. Cattle fed the all-forage diets produced steaks that were inferior ($P<.05$) in retail acceptability and were scored lower ($P<.05$) for all palatability determining characteristics. Grass-finished beef has been determined to be more variable in such quality factors as flavor (Cross and Smith, 1976; Harrison et al., 1978; Purchas and Davis, 1974; Wanderstock and Miller, 1948; Wheeling et al., 1975) and lean color (McCambell and MacKintosh, 1927) than grain-finished beef. Allen et al. (1976), Craig et al. (1959), Berry et al. (1977), and Meyer et al. (1960) concluded that meat from grass-finished cattle was less desirable in retail acceptability than grain-finished cattle because of darker colored lean. Grain-fed cattle were superior in all carcass qualitative traits, lean color and dressing percentage. Loin steaks from grain-fed steers were more tender as evaluated by Warner-Bratzler shear and were superior in retail acceptability than grass-fed steers.

Other researchers have concluded that grain-finished cattle produce muscle with superior flavor and tenderness traits when compared with muscle obtained from cattle fed high forage diets (Chapman et al., 1961; McCampbell, 1972; Kropf et al., 1975; Meyer et al., 1960). Contrasting results were reported by Huffman (1974), Bidner et al. (1981), and Oltjen et al. (1971) who reported that muscle from forage finished steers have comparable or superior palatability traits when compared with muscle from grain-fed cattle.

Reagan et al. (1977) studied the palatability of grass and grass-grain fed beef from 63 beef ribs obtained from carcasses of known grass-grain feeding regimens. Grain-fed cattle had higher marbling scores and quality grades than carcasses from grass-fed cattle. Loin steaks from grass-fed beef carcasses had significantly more moisture ($P<.05$) than steaks from the grain-fed beef.

Smith et al. (1977) studied the influence of feeding regimen (forage-backgrounding and forage-finishing) and biological type (small vs large) on growth, composition and palatability of steers. Two-hundred forty steers were placed on five different types of feeding regimens. The regimens included A = winter growing ration (2.18 Mcal ME/kg), summer grazing, 60%-forage finishing ration (2.84 Mcal ME/kg); B = same as A, except 20%-forage finishing ration (3.11 Mcal ME/kg); C = 96.6%-forage ration (2.40 Mcal ME/kg); D = 96.6%-forage ration switched to 60%-forage ration; E = 60%-forage ration. Faster gains were reported for the cattle on the highest energy diets. Feeding regimen also significantly affected fat thickness. External fat thickness increased with days on feed. Regimen had no effect on longissimus muscle area (P>.05). When carcasses were adjusted to equal carcass weights, regimen did not affect (P>.05) any taste panel traits (tenderness, juiciness, flavor or overall acceptability), fat color or final maturity. Biological type of cattle (small vs large) had no effect on either Warner-Bratzler shear force or any sensory panel attributes.

II. FEEDING REGIMENS AND AGE OF ANIMAL AS THEY AFFECT CONNECTIVE TISSUE

Miller et al. (1983) fed steers a high-energy diet for 185 days prior to slaughter to compare collagen solubility and palatability of beef from youthful and mature carcasses. Carcass maturity class did not affect sensory characteristics or shear force values of the cooked rib steaks. Total collagen content of samples from the longissimus muscle increased as carcass maturity increased, but did not affect percentage of soluble collagen.

Foehse (1981) analyzed uncooked and cooked samples of loin steaks for hydroxyproline. No significant differences in total, soluble or insoluble collagen attributable to nutritional regimen were reported. It was postulated that an adverse effect on tenderness of steaks from the forage-fed animals is the possible induced toughening effect of cold shortening during postmortem chilling of these carcasses.

Reagan et al. (1976) studied the age-related traits affecting the tenderness of the bovine longissimus muscle. Forty cattle ranging in age from 10 months to 27 years at the time of slaughter were placed into three chronological age groups: group I = 305 to 1033 days, group II = 1,332 to 2,927 days and group III = 3,635 to 9,828 days. Percentage fat, total collagen content, shear force value or sensory panel ratings for juiciness, tenderness and amount of connective tissue were not different for any of the age groups. Reagan et al. (1976) disagreed with earlier reports from Hiner and Hankins (1950), Walter et al. (1965) and Tuma et al. (1962) who found that younger cattle produce more tender meat upon cooking than do older cattle. The oldest cattle had a lower ($P<.05$) percentage of moisture and soluble collagen than the youngest cattle. Total chemically determined collagen was related to higher ($P<.05$) sensory panel scores for juiciness and lower ($P<.05$) scores for tenderness (less tender) and amount of connective tissue; but total collagen content was not associated with actual age of the animal. Chronological age of the animal positively influenced percentages of soluble collagen and shear force values. Tenderness, as evaluated by sensory panel, was comparable in all of the age groups ($P<.01$). As total collagen increased, juiciness ratings increased ($P<.05$) and subjective tenderness ratings decreased ($P<.05$). Fat level has been reported to be associated with sensory panel perceived juiciness (Berry, 1972; Doty and Pierce, 1961; Simone et al., 1959) and tenderness ratings (Husaini et al., 1950; Cover et al., 1956; Doty and Pierce, 1961). Reagan et al. (1976) also found that the relationships between soluble collagen percentages and subjective measurements of tenderness were not significant, but soluble collagen percentage was related to shear force values ($r = -.35$) ($P<.05$) and to chronological age ($r = -.47$) ($P<.01$).

Cross et al. (1973) studied the effects of intramuscular collagen and elastin on bovine muscle tenderness. Fifteen Hereford females in three chronological age groups (Group I = 305-642 days; Group II = 1382-1396 days; and Group III = 3635-5096 days) were used in the study. Age groups differed significantly (P<.05) in initial and sustained juiciness ratings, initial and muscle fiber tenderness ratings, shear force values, amount of connective tissue ratings and percentages of fat and moisture. Connective tissue ratings were positively correlated with unadjusted and adjusted percentage of soluble collagen. The correlation coefficients between measures of tenderness and chemically determined connective tissue components were lower in the Cross et al. (1973) study than those reported by Herring et al. (1967) and Smith and Carpenter (1970). The correlation coefficients for the sensory rating of amount of connective tissue compared to soluble collagen percentage, total collagen percentage and total hydroxyproline were .31, -.20 and -.21 respectively. Chemically determined amount of connective tissue was more closely associated with ratings for amount of connective tissue than with ratings for muscle fiber tenderness.

Herring et al. (1967) studied the factors affecting collagen solubility in 15 bovine longissimus dorsi and 15 bovine semimembranosus muscles. Solubility of intramuscular collagen was studied as affected by chronological maturity. Collagen became more insoluble in both longissimus dorsi and semimembranosus muscles as the animals became older. Collagen solubility was also higher (P<.05) in the longissimus dorsi and semimembranosus of the younger animals compared to the E maturity group, which possessed the largest amount of mature collagen. Collagen solubility was also related (P<.01) to sensory panel tenderness in both the longissimus dorsi (r=.77) and semimembranosus muscles (r=.81). Within maturity group, correlation coefficients of soluble collagen and tenderness were low and nonsignificant (P>.05). Collagen content was not different in longissimus dorsi muscles from animals in the A, B, and E maturity groups. Collagen content was not related (P>.05) to sensory panel tenderness in either muscle (r= -.42 and -.48 for longissimus dorsi and semimembranosus, respectively). Collagen solubility did not change with post-mortem aging up to ten days.

Burson (1985) studied the effects of muscle, heat and sex on the proportions of types I and III bovine intramuscular collagens. Longissimus dorsi (LD), biceps femoris (BF), semimembranosus (SM) and semitendinosus (ST) muscles were sampled from eight, 18-month old Simmental bulls 7 days after slaughter. They were evaluated for sensory panel traits, Warner-Bratzler shear and total collagen content. Total collagen content was different (P<.05) for each muscle with the LD < SM < ST < BF. The longissimus muscles were the most tender muscles (P<.05) and were more tender than biceps femoris as determined by Warner-Bratzler shear force and sensory panel ratings for connective tissue amount and overall tenderness. Percentage of type III collagen was correlated (P<.05) with sensory panel connective tissue amount (r = .48) and overall tenderness (r = .48). The relationship of fiber type to tenderness was not strong.

CHAPTER III

MATERIALS AND METHODS

Eighty-six steers consisting of Angus (n=40), Hereford (n=21), Angus X Hereford (n=10) and crossbred steers (n=15) from the Plateau Experiment Station, Crossville, TN, were used to study the effect of pasture type and different grain feeding periods on carcass characteristics, muscle composition and sensory traits of loin steaks. Pasture types included ryegrass (n=18), Kentucky 31 Fescue (endophyte infested) (n=18), orchardgrass (n=18), and fescue-clover mixed pasture (n=32). The grain ration was whole shelled corn fed ad libitum and nutritionally balanced with a pelleted 36% protein supplement and fed at a rate of .5 kg/hd/d. After backgrounding for 8 months, the steers on ryegrass, Kentucky 31 Fescue and orchardgrass pastures were randomly assigned by breed type to grain feeding periods of 0, 56 or 112 days (DOF). The fescue-clover backgrounded calves were randomly placed into a grain feeding group of 0, 28, 56, 84, 112, or 140 DOF. All animals were slaughtered at Lay's Packing Co., Knoxville, Tennessee.

After slaughter the carcasses were chilled for 48 h, ribbed and evaluated by a USDA grader for quality and yield grades. Also, lean color, lean firmness, and lean texture were subjectively evaluated by University of Tennessee personnel. The left hindquarter of each carcass was transported to the University of Tennessee Meat Laboratory for fabrication and collection of research samples.

The hindquarters were weighed, then broken into wholesale loin, flank and round according to the procedure of Wellington (1953). The femur was removed from the round and the biceps femoris was removed from the round and the loin, trimmed of fat and connective tissue, and weighed. Femur length was measured and the cross section area of the biceps femoris was determined at 55% of the length of the muscle from the anterior end by tracing the area and measuring with a compensating polar planimeter.

After aging the shortloin for 10 d, steaks were removed from the anterior end. The first steak (3.7 cm) was stripped of all epimysium, frozen in liquid nitrogen, powdered in a Waring blender, and used for fat, moisture, and hydroxyproline analysis. Steaks two and three (2.5 cm) were used for sensory panel training and sensory panel evaluation.

Moisture and fat percentages of raw and cooked longissimus muscle were determined by the AOAC (1984) vacuum oven drying and Soxhlet ether extraction procedures, respectively.

Hydroxyproline content of the longissimus muscle was determined using duplicate freeze powered 4 g samples that were heated for 70 min. at 77C in 12 ml of .25 strength Ringer's solution (Hill, 1966). The samples were allowed to cool for 20 min. They were then centrifuged at 2^{o}C and 3,000 G for 10 min. The supernatants were decanted into dilution bottles. Eight milliliters of .25 strength Ringers solution were added to the centrifuge tubes which were centrifuged again under the same conditions to wash any of the remaining soluble proteins. The supernatant was again decanted off. The residue was removed from the centrifuge tube and placed into a dilution bottle. Ten milliliters each of distilled water and concentrated hydrochloric acid (12N) were placed into each of the residue bottles and autoclaved 18 h at 124C. Twenty milliliters of concentrated hydrochloric acid were placed into each of the supernatant bottles and autoclaved under the same conditions.

After autoclaving, 3 g of animal charcoal were added to each of the bottles and each bottle was shaken for 4 min on a mechanical shaker. Next, the contents of each dilution bottle were filtered through a Whatman #2 filter paper into a 250 ml distillation flask. The samples were then evaporated until dry on a Buchler Flash-Evaporator (Model 71236). After evaporation, 10 ml of distilled water and 4 drops of methyl red indicator were added to the flasks. The flasks were filtered again through Whatman #2 filter paper. The supernatant samples were filtered into 250 ml volumetric flasks and the residue into 500 ml volumetric flasks. Both flasks were brought up to volume with distilled water.

Hydroxyproline standards were made up in the range of 0, 2, 4, 8, 10, and 20 ug/ml. One milliliter of each of the standards and 1 ml of each of the residues and supernatants were pipetted into 50 ml test tubes. Next, 2 ml of isopropyl alcohol were pipetted into each of the test tubes. One milliliter of oxidant solution was then added to each of the tubes. After 4 min, 13 ml of Ehrlich's reagent was added to stop the reaction. The test tubes were allowed to stand for 18 h and absorbance was read at 558 nm on a Hitachi spectrophotometer (Model 100-60). Collagen content was determined by multiplying the hydroxyproline content of the supernatant by 7.52 and that of the residue by 7.25 (Bergman and Loxley, 1963).

Sensory panelists subjectively evaluated tenderness, juiciness, and overall acceptability using an 8 point scale (1=extremely undesirable, and 8=extremely desirable). Flavor was also evaluated on an 8 point scale where 1=extreme milky oily flavor and 8=extreme beef fat flavor. Panel members were served six samples per day from the longissimus muscle. Each panelist was served a 1.25 cm^2 sample of each steak. Steaks were cooked in a rotary Despatch Oven to an internal temperature of 70C (Cross et al., 1978). Each panelist was served one sample at a time under red light.

Steak four (2.5 cm) was used for Warner-Bratzler shear force determination, volatile, non-volatile, and total cooking loss. Steaks were cooked to 70C internal temperature using a Despatch Oven. Nine cores were taken from each steak. Cores were identified according to the anatomical location within the steak. Three cores were taken from each of the three regions in the steak; medial side, center, and lateral side, and each core was sheared twice.

All data were analyzed by analysis of variance with pasture type and days on feed (DOF) as independent variables using the General Linear Model procedure of SAS (1985). Least square means were determined and separated using the probability of difference procedure of SAS (1982).

CHAPTER IV

RESULTS AND DISCUSSION

I. DAYS ON FEED AND PASTURE TYPE AS THEY AFFECT CARCASS TRAITS

Table 1 shows the least square means for carcass traits of steers fed grain 0, 56 or 112 days. Results of the analysis of variance for the carcass traits are given in Appendix A. Hot carcass weight (HCW) increased ($P<.05$) from 0 DOF (191.7 kg) to 56 DOF (257.8 kg) and again from 56 DOF to 112 DOF (300.6 kg). Dinius and Cross (1978), Hedrick et al. (1983), and Greene et al. (1989) also found similar results that cattle tend to increase in carcass weight as they remain on feed longer and become older.

The adjusted fat thickness increased ($P<.05$) from 4.3 mm for the 0 DOF cattle to 11.4 mm for the 112 DOF cattle. All three DOF groups were different ($P<.05$) from each other in adjusted fat thickness. Increasing DOF not only increased hot carcass weight (HCW) but also increased adjusted fat thickness. Dinius and Cross (1978), Epley et al. (1968), and Smith et al. (1977) also found that as cattle were fed longer adjusted fat thickness increased. The ribeye area for the 0 DOF cattle was 58.4 cm^2 compared to 73.1 cm^2 for the 56 DOF cattle and 75.6 cm^2 for 112 DOF cattle. Increasing the time cattle were fed concentrate increased ($P<.05$) ribeye area from 0 to 56 DOF but not from 56 to 112 DOF. USDA yield grade was affected similarly by DOF. The least square mean yield grades were 1.8, 2.1, and 2.8 for 0, 56, and 112 DOF, respectively. Cattle from this study never surpassed the maximum USDA yield grade of 2.8. Therefore, steers can be fed in drylot

TABLE 1. LEAST SQUARE MEANS FOR CARCASS TRAITS BY DAYS ON FEED

Carcass trait	Days on feed 0	56	112
Hot carcass wt., kg	191.7^{a}	257.8^{b}	300.6^{c}
Adj. fat thickness, mm	4.3^{a}	8.6^{b}	11.4^{c}
Ribeye area, cm^2	58.4^{a}	73.1^{b}	75.6^{b}
Yield grade	1.8^{a}	2.1^{b}	2.8^{c}
Maturity^{d}	1.4^{a}	1.4^{a}	1.4^{a}
Marbling^{e}	3.4^{a}	4.5^{b}	5.3^{c}
Quality grade^{f}	2.6^{a}	5.1^{b}	7.6^{c}
Lean firmness^{g}	4.6^{a}	5.7^{b}	5.6^{b}
Hindquarter wt., kg	44.4^{a}	61.2^{b}	68.5^{c}
Round wt., kg	23.5^{a}	30.3^{b}	33.1^{c}
Loin wt., kg	14.4^{a}	19.8^{b}	23.2^{c}
Flank wt., kg	4.4^{a}	5.8^{b}	7.1^{c}
Cod wt., kg	0.6^{a}	0.8^{a}	1.2^{b}
Kidney fat wt., %	1.3^{a}	2.3^{b}	2.7^{c}
Femur wt., kg	1.8^{a}	1.8^{a}	1.9^{b}
Femur length, cm	36.0^{a}	36.7^{a}	38.0^{b}
Biceps femoris wt., kg	3.8^{a}	4.8^{b}	5.3^{c}
Biceps femoris area, cm^2	95.9^{a}	115.6^{b}	119.4^{b}

^{abc}Least square means in the same row bearing different superscript letters differ ($P<.05$).

^{d}1.0 = A^{0}; 1.2 = A^{20}; 1.4 = A^{40}.

^{e}1 = devoid; 5 = small; 10 = abundant.

^{f}1 = low standard; 6 = high select; 12 = high prime.

^{g}1 = very soft; 5 = slightly firm; 8 = very firm.

up to 112 d and will produce carcasses that are acceptable in external fat thickness. These findings are consistent with the results reported by Greene et al. (1989). They reported that steers fed concentrate 0, 56 and 112 DOF produced carcasses with 1.6, 1.9 and 2.8 yield grades, respectively.

Maturity scores for all three DOF groups were 1.4 (1.4=A^{40}) and did not differ (P>.05) (Table 1). Degree of marbling increased with increasing DOF (P<.05). Marbling scores were 3.4, 4.5, and 5.3 (3.4=Traces^{40}, 4.5=Slight^{50}, and 5.3=Small^{30}) for 0, 56 and 112 DOF groups, respectively. Likewise, USDA quality grade improved across DOF. The 0 DOF cattle graded high Standard, the 56 DOF cattle graded average Select and the 112 DOF steers graded low Choice. Steers from this study produced higher quality grading carcasses than those reported by Greene et al. (1989). Greene et al. (1989) found that steers fed a concentrate diet for 0, 56 and 112 DOF, produced average Standard, low Select, and high Select quality grading carcasses, respectively. Feeding high concentrate diets for longer time periods increased final quality grades of the steers which concurs with reports by Harrison et al. (1978) and Zinn et al. (1961). This study would suggest that steers must be fed at least 112 d to assure a minimum quality grade of low Choice. Although, carcass quality grade has been implicated to affect palatability scores, research has indicated that it may not be necessary to feed cattle to the Choice grade to insure beef with desirable palatability characteristics (Dikeman, 1987). Lean firmness was ranked on a scale from 1 to 8 (1=very soft, 8=very firm). Lean firmness for the 0 DOF cattle was softer (slightly soft) (P<.05) than the 56 or 112 DOF steers (slightly firm). A possible explanation for this could be due to the differences in marbling score and external fat thickness for the 0 DOF group.

Marbling scores and adjusted fat thickness increased from 0 to 56 DOF and again from 56 to 112 DOF. Therefore, increases in intramuscular and external fat may have provided added support to the longissimus muscle when chilled.

Hindquarter weights increased from 44.4 kg to 68.5 kg from 0 to 112 DOF, respectively (Table 1). Likewise, round weight, loin weight, flank weight and kidney fat weight percentage increased ($P<.05$) significantly with DOF. The 112 DOF cattle had heavier cod fat weights and more kidney fat (weight percentage) than the 0 or 56 DOF steers ($P<.05$). Kidney fat weight percentage increased linearly from 1.3% to 2.7% from the 0 to the 112 DOF groups. Harrison et al. (1978) also found that steers slaughtered off grass had less (2.7%) kidney fat percentage than steers fed concentrate for 98 d (3.3%). Even though kidney fat weight percentage increased linearly from 0 to 112 DOF, none of the carcasses from any of the DOF groups contained excess internal fat.

As the cattle grew and became older, bone increased in length and weight and Biceps femoris muscle increased in weight and area (although, not always significant statistically). Continued bone and muscle growth was observed up to 112 DOF. The 112 DOF steers had longer and heavier femurs ($P<.05$) than the other two groups (Table 1). Biceps femoris weights increased across DOF groups ($P<.05$). Biceps femoris areas were smaller ($P<.05$) for the 0 DOF cattle (95.9 cm^2) and increased to 112 DOF (119.4 cm^2). The cattle, therefore, had not reached the plateau of their physiological growth curves. Muscle to bone ratios (Biceps femoris weight : femur weight) were 2.1, 2.7, and 2.8 to 1 for the 0, 56 and 112 DOF groups, respectively. Muscle to bone ratio increased up to 112 DOF. Therefore muscle growth was occurring faster than bone growth as the steers were left on feed longer. Similar results were reported by Reviere (1982) who found that muscle to bone ratios (Biceps femoris weight : femur weight) for 0, 56 and 112 DOF steers were 2.3, 2.7 and 2.7 to 1, respectively.

Table 2 contains the least square means for carcass characteristics by pasture type. The presence of endophyte in the fescue pastures may have provided added stress on the steers which resulted in inferior carcass and wholesale cut gains. The presence of endophyte in the pastures resulted in less carcass gains of approximately 10 to 20 kg per head. Steers grown on the fescue and fescue-clover mixed pasture had lighter ($P<.05$) hot carcass weights than the orchardgrass fed cattle. The fescue-clover backgrounded cattle had the lightest carcasses at 239.3 kg and the orchardgrass cattle had the heaviest at 268.3 kg. The ryegrass cattle did not differ ($P>.05$) in HCW from steers on any of the other pasture types. The fescue-clover backgrounded cattle had a lower ($P<.05$) mean adjusted fat thickness than steers on any of the other pastures. The orchardgrass backgrounded cattle were fatter ($P<.05$) than any other treatment. Ryegrass and Kentucky 31 Fescue fed cattle were not different ($P>.05$) from each other in carcass adjusted fat thickness. Ribeye areas ranged from 67.7 cm^2 for the fescue-clover fed steers to 70.2 cm^2 for the orchardgrass fed steers; but, ribeye area of the carcasses did not vary across pasture types ($P>.05$). Therefore, external fat was affected more by pasture type that the steers were backgrounded on than was ribeye area. The orchardgrass fed cattle were significantly fatter than the cattle from the other pasture types, and thus had a less desirable USDA yield grade of 2.6 compared to 2.2, 2.2, and 2.0 for

TABLE 2. LEAST SQUARE MEANS FOR CARCASS TRAITS BY PASTURE TYPE

Carcass trait	Pasture type[d]			
	Ryegrass	Fescue	Orchardgrass	Fescue-clover
Hot carcass wt., kg	252.5^{ab}	240.0^{a}	268.3^{b}	239.3^{a}
Adj. fat thickness, mm	7.9^{b}	8.4^{b}	10.7^{c}	5.8^{a}
Ribeye area, cm^2	69.0^{a}	69.1^{a}	70.2^{a}	67.7^{a}
Yield grade	2.2^{a}	2.2^{a}	2.6^{b}	2.0^{a}
Maturity[d]	1.4^{b}	1.4^{ab}	1.4^{a}	1.4^{ab}
Marbling[e]	4.5^{a}	4.3^{a}	4.5^{a}	4.3^{a}
Quality grade[f]	4.8^{a}	4.4^{a}	5.1^{a}	4.7^{a}
Lean firmness[g]	5.4^{ab}	5.5^{b}	4.8^{a}	5.3^{a}
Hindquarter wt., kg	57.4^{a}	55.2^{a}	62.3^{b}	57.4^{ab}
Round wt., kg	28.6^{ab}	28.2^{a}	30.7^{b}	28.4^{a}
Loin wt., kg	19.2^{a}	17.9^{a}	21.1^{b}	18.4^{a}
Flank wt., kg	5.9^{b}	5.7^{ab}	6.4^{b}	5.2^{a}
Cod wt., kg	0.7^{a}	0.7^{a}	1.2^{b}	0.8^{a}
Kidney fat wt., %	1.1^{a}	1.1^{a}	1.1^{a}	1.0^{a}
Femur wt., kg	1.9^{a}	1.7^{a}	1.9^{a}	1.9^{a}
Femur length, cm	37.0^{a}	36.2^{a}	36.9^{a}	37.6^{b}
Biceps femoris wt., kg	4.6^{ab}	4.4^{a}	4.9^{b}	4.6^{ab}
Biceps f. area, cm^2	108.7^{a}	103.0^{a}	119.8^{b}	109.8^{a}

[abc]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[d]1.0 = A^{0}; 1.2 = A^{20}; 1.4 = A^{40}.

[e]1 = devoid; 5 = small; 10 = abundant.

[f]1 = low standard; 6 = high select; 12 = high prime.

[g]1 = very soft; 5 = slightly firm; 8 = very firm.

the ryegrass, Kentucky 31 Fescue and fescue-clover backgrounded cattle, respectively. Mean USDA yield grades for the steers on the other pasture types did not differ ($P>.05$).

Carcass maturity had some variability but carcass USDA quality grade did not differ among pastures (Table 2). The orchardgrass fed cattle were statistically younger ($P<.05$) in carcass maturity than the ryegrass fed cattle, though both were evaluated to have a 1.4 (A^{40}) maturity score. This occurred because the orchardgrass fed steers had a mean 1.38 (A^{38}) maturity score and the ryegrass fed steers had a 1.43 (A^{43}) maturity score, which both rounded to a 1.4 (A^{40}) maturity score. Though the difference in maturity was statistically different between the ryegrass and the orchardgrass backgrounded cattle, both groups of cattle were within the USDA A maturity group. The degree of marbling varied from 4.3 (Slight^{30}) for the fescue and fescue-clover backgrounded cattle to 4.5 (Slight^{50}) for the orchardgrass and ryegrass fed cattle but were not different ($P>.05$). Therefore, since maturity and marbling scores were similar for all groups, none of the pasture treatments were different ($P>.05$) from each other with respect to USDA quality grade. The fescue-fed steers had firmer lean ($P<.05$) than the orchardgrass and fescue-clover fed steers. No other difference in lean firmness was observed among any of the other groups.

The orchardgrass cattle produced heavier hindquarters (62.3 kg) than either the ryegrass (57.4 kg) or fescue fed cattle (55.2 kg) ($P<.05$), but were not different ($P>.05$) than the fescue-clover fed cattle (57.4 kg). The orchardgrass backgrounded cattle also produced heavier round weights than the fescue and the fescue-clover mixed pasture cattle ($P<.05$). A heavier loin weight ($P<.05$) was also observed in the orchardgrass cattle (21.1 kg) compared to steers from the ryegrass, fescue, and fescue-clover mixed pastures (19.2, 17.9 and 18.4 kg, respectively). The fescue-clover steers produced the lightest flanks (5.2 kg) which were slightly lighter than the ryegrass (5.9 kg) and the orchardgrass cattle (6.4 kg) ($P<.05$). Because the orchardgrass fed steers were fatter and had heavier carcass weights, they produced more ($P<.05$) cod fat (weight basis) than cattle from the other pasture types. The heavier wholesale cut weights of the orchardgrass cattle were probably the result of both increased fat and muscle deposition as shown by increased carcass adjusted fat thickness, larger ribeye areas and larger biceps femoris areas.

Kidney fat weight percentage of the carcasses did not vary ($P>.05$) across pasture type (Table 2). Femur weights were not different ($P>.05$) across pastures, though the fescue-clover cattle had longer femurs ($P<.05$) than the other pasture types. Biceps femoris weights were heavier for the orchardgrass fed steers than the fescue fed steers. This led to a correspondingly larger biceps femoris area (119.8 cm^2) for the orchardgrass fed cattle than any of the other pasture types. Muscle to bone ratios (Biceps femoris weight : femur weight) were 2.4, 2.6, 2.6 and 2.4 to 1 for the ryegrass, Kentucky 31 Fescue, orchardgrass and fescue-clover backgrounded cattle, respectively. Little difference in muscle to bone ratio across pasture type was observed.

Figure 1 shows the interaction between DOF and pasture type for subjectively evaluated (USDA Grader) kidney, pelvic and heart (KPH) fat percentage. The Kentucky 31 Fescue, orchardgrass and fescue-clover steers all had an increase in KPH fat percentage from 0 to 112 DOF. The Kentucky 31 Fescue pastured cattle did not, however, increase in internal fat

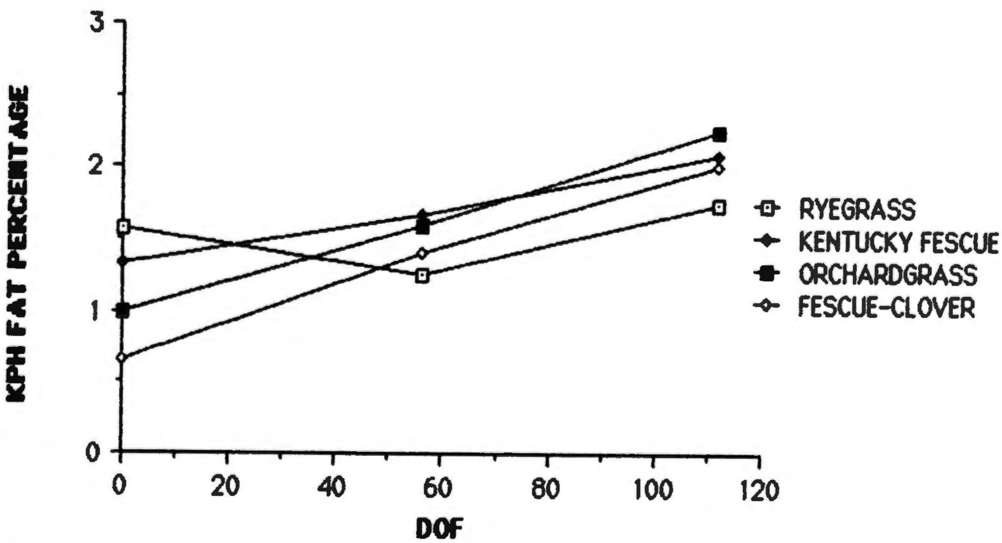

FIGURE 1. Interaction Means for Days on Feed and Pasture Type for Kidney, Pelvic and Heart Fat Percentage.

percentage at a rate as fast as the orchardgrass and fescue-clover fed cattle. The ryegrass backgrounded cattle decreased in percentage KPH from 0 to 56 DOF then increased up to 112 DOF. The 0 DOF steers had 1.3% kidney fat on a weight basis. The USDA grader evaluated the 0 DOF steers to have 1.1% internal fat. The 56 DOF steers had 2.3% kidney fat on a weight basis and was evaluated to have 1.4% fat by the USDA Grader. Likewise, the 112 DOF steers had 2.7% kidney fat on a weight basis and was evaluated to have 1.8% fat by the USDA Grader. Therefore the USDA Grader was inconsistent with evaluation of internal fat percentage after 56 DOF. This may contribute to the fact that the ryegrass-fed steers, which were evaluated by the grader, declined in internal fat percentage from 0 to 56 DOF, then increased up to 112 DOF. Also, no interaction was observed between DOF and pasture type for kidney, pelvic and heart fat weight percentage.

Figure 2 shows the DOF and pasture type interaction for lean color. The endophyte infected Kentucky 31 Fescue steers had a more cherry red color for the 0, 56 and 112 DOF groups than steers from any other pasture. This is in contrast to results reported by Harrison et al. (1978) who found that nutritional regimen did not affect lean color. Longissimus muscle of the carcasses from the orchardgrass and fescue-clover cattle tended to become more cherry red at 56 DOF then became darker red at 112 DOF. Muscle from the ryegrass cattle became darker in color from 0 to 56 DOF, then improved in color to slightly dark red at 112 DOF.

Figure 3 shows the interaction between DOF and pasture type for lean texture. Lean from the Kentucky 31 Fescue and the orchardgrass fed cattle became finer in texture from 0 to 112 DOF which agreed with

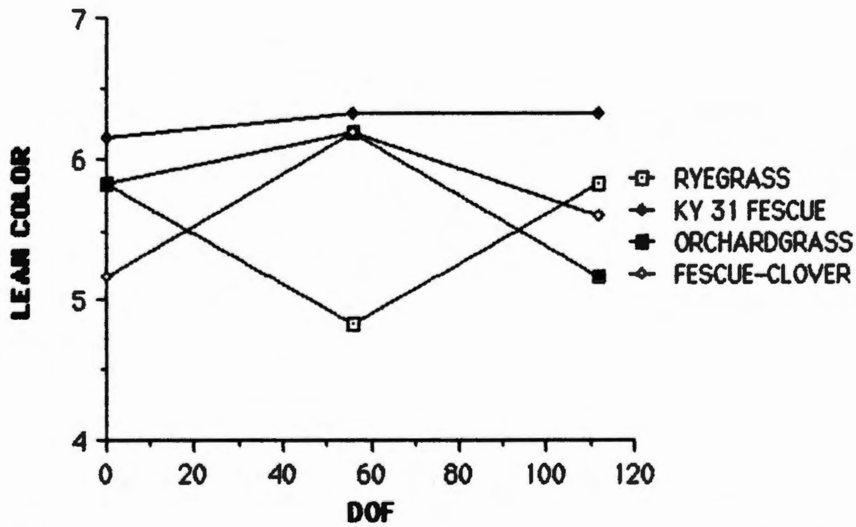

FIGURE 2. Interaction Means for Days on Feed and Pasture Type for Lean Color[a].

[a]1 = black; 4 = moderately dark red; 8 = light grayish red;

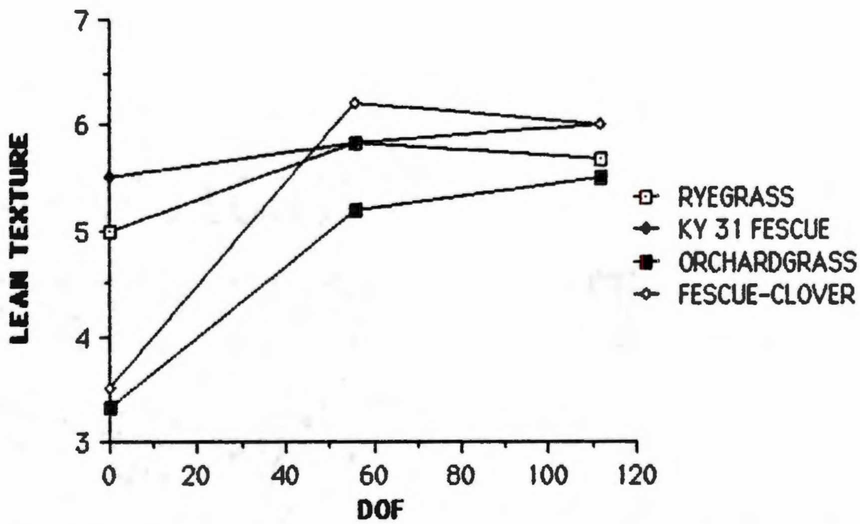

FIGURE 3. Interaction Means for Days on Feed and Pasture Type for Lean Texture[a].

[a]1 = very coarse; 4 = slightly coarse; 8 = very fine;

Harrison et al. (1978) who also found that lean texture of the longissimus muscle became finer in longer fed cattle. Lean from the ryegrass and fescue clover backgrounded cattle became finer textured from 0 to 56 DOF but then became slightly more coarse in texture from 56 to 112 DOF.

II. DAYS ON FEED AND PASTURE TYPE AS THEY AFFECT CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE

Table 3 shows the least square means for chemical and physical characteristics of raw and cooked longissimus muscle by DOF. The analysis of variance results for the chemical and physical characteristics of the longissimus muscle are given in Appendix B. The 0 DOF cattle had more moisture ($P<.05$) and less lipid percentage on a raw weight basis, than either the 56 or the 112 DOF steers. This concurs with the increased longissimus marbling score from 0 to 112 DOF. Steaks from the 112 DOF cattle had less non-volatile cooking loss than steaks from either the 0 or the 56 DOF steers ($P<.05$). The 0 DOF group had the greatest total cooking loss percentage (21.40%) and was different from the 112 DOF (19.43%) group ($P<.05$). These results are in conflict to those reported by Reviere (1982) who found that cattle slaughtered off pasture have less non-volatile and total cooking loss than cattle fed concentrate for 112 DOF. This study concluded that the 0 DOF group encountered greater moisture loss (rather than fat) contributing to total cooking loss than the steaks from the longer fed groups.

TABLE 3. LEAST SQUARE MEANS FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE OF STEERS FED GRAIN 0, 56 OR 112 DAYS

	Days on feed		
Dependent variable	0	56	112
Moisture, raw, %	75.42[b]	74.01[a]	72.93[a]
Moisture, cooked, %	66.03[a]	66.14[a]	64.95[b]
Fat, raw, %[d]	2.57[a]	3.96[b]	4.83[b]
Fat, cooked, %[d]	4.26[a]	6.28[b]	7.14[b]
Non-volatile cooking loss, %	7.04[b]	7.38[b]	6.43[a]
Total cooking loss, %	21.40[a]	20.92[ab]	19.43[b]
Soluble collagen, mg/g	2.93[b]	2.64[a]	1.86[a]
Insoluble collagen, mg/g	2.91[a]	4.06[b]	3.54[a]
Total collagen, mg/g	5.85[a]	6.71[a]	5.40[a]
Soluble collagen, %	47.31[b]	37.78[a]	34.80[a]
Insoluble collagen, %	52.68[a]	62.22[ab]	65.20[b]
Warner-Bratzler, kg	4.58[b]	3.44[a]	3.22[a]
Medial section shear, kg	5.01[c]	3.57[b]	3.00[a]
Center section shear, kg	4.09[c]	3.15[b]	3.09[a]
Lateral section shear, kg	4.63[c]	3.70[b]	3.60[a]

[abc]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[d]Wet weight basis.

Comparing the cooked steaks (Table 3), the 112 DOF group had the lowest percentage moisture (64.95%) which was less than steaks from the 0 DOF (66.03%) and the 56 DOF (66.14%) steers. The 0 DOF cattle had significantly less cooked fat percentage than either of the other two groups. This is occurred because the 0 DOF steers had lower quality grading carcasses and contained less fat on a raw weight percentage basis. This is in agreement with Renk et al. (1985) who reported that cooked steaks from higher quality grading carcasses contain more fat than do cooked steaks from lower quality grading carcasses.

There was a greater amount of soluble collagen ($P<.05$) in steaks from the 0 DOF (2.93 mg/g) steers than the 56 (2.64 mg/g) and the 112 DOF (1.86 mg/g) steers (Table 3). This trend was also noticed in the percentage of soluble collagen. An increase of insoluble collagen was noticed from 0 to 56 DOF but then decreased from 56 to 112 DOF. The 56 DOF steers possessed more insoluble collagen than either the 0 or the 112 DOF steers ($P<.05$). Though there were differences in soluble and insoluble collagen, total collagen was not different for any of the DOF groups ($P>.05$). This is in agreement with Foehse (1981) who found that total collagen was not affected by length of feeding. The percentage of insoluble collagen increased from 0 DOF (52.68%) up to 112 DOF (65.20%). The 0 DOF steers had significantly lower insoluble collagen percentage than the 112 DOF steers. The Warner-Bratzler shear force mean was greater ($P<.05$) for steaks from the 0 DOF steers than for either the 56 or the 112 DOF steers (Table 3). Warner-Bratzler shear force more closely paralleled fat content of the loin steaks than did chemically determined collagen. Steaks from the 0 DOF steers had less percentage fat and larger Warner-Bratzler shear values than steaks from either the 56 or 112 DOF groups. Sensory panel results, also concur with the shear findings. This agrees with reports by Kropf et al. (1975) and Bowling et al. (1977) who found that steaks from grain-fed beef had lower shear force than those from grass-fed beef. Warner-Bratzler shear force values were obtained for medial, center and lateral sections of the loin steaks. Shear values from cattle fed 0, 56 and 112 d were pooled. Least square mean Warner-Bratzler shear force values for the medial, center and lateral sections were 3.92, 3.57, and 4.00 kg, respectively. Cores taken from the center section were more tender ($P<.05$) than either the medial or lateral sections. No difference in shear force was observed between the medial and lateral sections ($P>.05$). Thermometers were placed into the center of each steak during cooking. Therefore the center of each steak reached 70C internal temperature. Since internal temperature was not monitored in the medial and lateral sections of the steak, they may have reached a higher internal temperature than the center section. Research has indicated that an increase in internal temperature of muscle during cooking results in a decrease in tenderness (RMC Proceedings, 1987).

Shear values of cores taken from the medial, center and lateral sections were compared across DOF for Warner-Bratzler shear force (Table 3). All three sections decreased in shear force from 0 to 56 DOF ($P<.05$) and again from 56 to 112 DOF ($P<.05$). Since adjusted fat thickness of the carcasses increased with DOF (Table 1), there may have been less cold shortening in the longer fed cattle due to the added insulation of external fat during carcass chilling. Harrison et al. (1978) found that longissimus muscle from trimmer carcasses undergoes greater cold shortening than muscle from fatter carcasses.

Table 4 contains the least square means for chemical and physical characteristics of longissimus muscle from steers backgrounded on different pastures. The analysis of variance of this data is given in Appendix B. Pasture type had little effect on moisture percentage of the raw longissimus muscle even though the fescue fed cattle had more ($P<.05$) moisture on a raw weight basis than the orchardgrass fed cattle. Cooked longissimus dorsi moisture percentage did not vary across pastures, but the fescue fed cattle had significantly lower percentage lipid in the cooked steaks than the orchardgrass backgrounded cattle. This might have occurred because the fescue-fed cattle had slightly lower marbling scores in the longissimus muscle, although the differences were not significant. No difference in percentage fat on a raw, wet weight basis, were observed between cattle on any of the other pasture types. No differences were observed in either the non-volatile cooking loss percentage or total cooking loss for any of the pastures. Non-volatile cooking loss ranged from 6.66% for the fescue-clover cattle to 7.29% for the ryegrass cattle. Total cooking loss ranged from 20.09% for the fescue-clover backgrounded cattle to 21.29% for the ryegrass fed cattle.

The amounts (mg/g) of soluble collagen, insoluble collagen and total collagen (Table 4) were not different across pastures ($P>.05$). Miller et al. (1983) reported that collagen content does not differ between cattle in the same USDA maturity class. Therefore, one possible explanation of why collagen content did not differ between pasture types was because carcasses from all four pasture types were within the USDA A maturity group. Soluble collagen percentage was less ($P<.05$) for the ryegrass cattle (33.79%) than for the fescue fed cattle (51.06%). Conversely, the fescue fed

TABLE 4. LEAST SQUARE MEANS FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM STEERS BACKGROUNDED ON DIFFERENT PASTURES

	Pasture type			
Dependent variable	Ryegrass	Fescue	Orchardgrass	Fescue-clover
Moisture, raw, %	74.00[ab]	74.80[b]	73.26[a]	74.41[ab]
Moisture, cooked, %	65.68[a]	65.85[a]	65.10[a]	66.20[a]
Fat, raw, %[c]	3.85[a]	3.62[a]	4.10[a]	3.59[a]
Fat, cooked, %[c]	17.31[ab]	14.72[a]	18.68[b]	16.30[ab]
Non-volatile cook loss, %	7.29[a]	6.69[a]	7.15[a]	6.66[a]
Total cooking loss, %	21.29[a]	20.30[a]	20.66[a]	20.09[a]
Soluble collagen, mg/g	2.09[a]	3.01[a]	2.57[a]	2.23[a]
Insoluble collagen, mg/g	3.64[a]	3.00[a]	3.72[a]	3.66[a]
Total collagen, mg/g	5.73[a]	6.02[a]	6.30[a]	5.90[a]
Soluble collagen, %	33.79a	51.06b	37.69ab	37.31ab
Insoluble collagen, %	66.20[b]	48.93[a]	62.30[ab]	62.69[ab]
Warner-Bratzler, kg	3.87[a]	3.67[a]	5.58[a]	3.87[a]

[ab]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[c]Wet weight basis

cattle had less (P<.05) insoluble collagen (48.93%) than the ryegrass fed cattle (66.20%).

Warner-Bratzler shear force (Table 4) was not different (P>.05) for any of the pasture types. This agrees with sensory panel ratings for tenderness (Table 6). Sensory panel ratings for tenderness did not differ (P<.05) for steaks from any of the pasture types.

Figure 4 displays the interaction between DOF and pasture type for volatile cooking loss percentage. Steaks from the ryegrass, Kentucky 31 Fescue and fescue-clover fed cattle decreased in volatile cooking loss percentage from 0 to 56 DOF then increased slightly up to 112 DOF. The ryegrass backgrounded cattle had an inverse relationship. Volatile cooking loss increased up to 56 DOF (17.47%), then declined to 12.50% for the 112 DOF group. Percentage fat and moisture on a raw and cooked basis as well as collagen content were similar for the ryegrass fed cattle compared to the other pasture types. Therefore, differences in muscle composition of the ryegrass fed cattle cannot explain differences in volatile cooking loss percentage.

III. DAYS ON FEED AND PASTURE TYPE AS THEY AFFECT SENSORY CHARACTERISTICS OF BEEF LONGISSIMUS MUSCLE

Table 5 contains the least square means for sensory characteristics of longissimus muscle by days on feed. Appendix C shows the analysis of variance for sensory characteristics of the longissimus muscle of steers fed grain 0, 56 or 112 days. The day in which the samples were evaluated was used as a blocking variable in the statistical model. The day in which

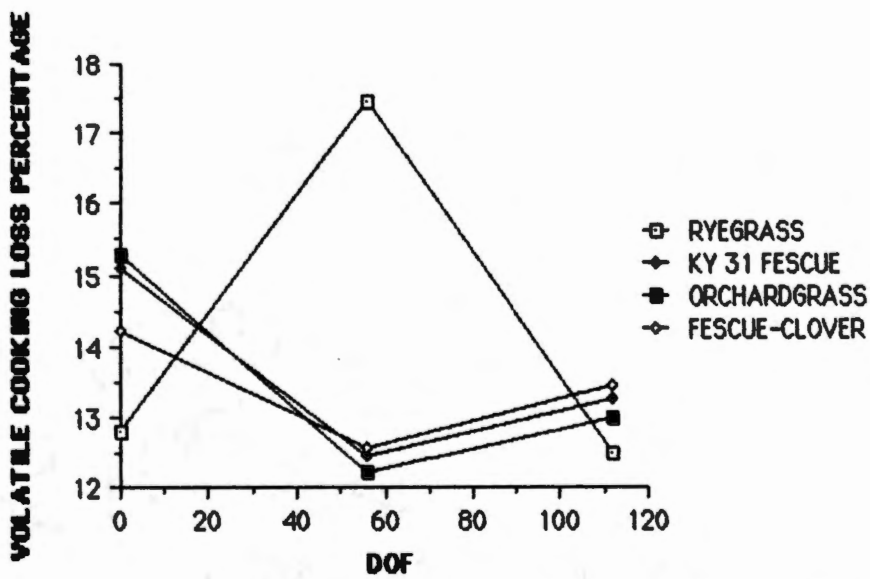

FIGURE 4. Interaction Means for Days on Feed and Pasture Type for Volatile Cooking Loss Percentage.

TABLE 5. LEAST SQUARE MEANS FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM STEERS FED GRAIN 0, 56 OR 112 DAYS

	Days on feed		
Sensory characteristic	0	56	112
Flavor[d]	3.99[a]	5.03[b]	5.42[c]
Juiciness[e]	4.58[a]	5.51[b]	5.61[b]
Tenderness[f]	4.59[a]	5.79[b]	5.85[b]
Overall acceptability[g]	3.66[a]	5.11[b]	5.46[c]

[abc]Least square means in the same row bearing different superscript letters differ ($P < .05$).

[d]Flavor: 1 = extreme milky oily; 4 = slight milky oily; 8 = extreme beef fat.

[e]Juiciness: 1 = extremely dry; 4 = slightly dry; 8 = extremely juicy.

[f]Tenderness: 1 = extremely tough; 4 = slightly tough; 8 = extremely tender.

[g]Overall acceptability: 1 = extremely undesirable; 4 = slightly undesirable; 8 = extremely desirable.

the samples were evaluated affected juiciness ($P<.004$), tenderness ($P<.019$) and overall acceptability ($P<.0002$) scores but did not affect flavor scores. This may have occurred because panelists did not always sample the steaks the same length time after preparation. Samples may have cooled and may have become drier from the time they were prepared to the time they were evaluated. Generally as DOF increased, flavor became a more typical beef fat flavor ($P<.05$). Bowling et al. (1977), Harrison et al. (1978), Westerling and Hedrick (1979), Brown et al. (1979), and Schroeder et al. (1980) found that flavor desirability increased as cattle were fed grain longer. The steaks became more juicy and more tender from 0 to 56 DOF ($P<.05$) but not from 56 to 112 DOF. Overall acceptability became more desirable from 0 to 56 DOF ($P<.05$), and from 56 to 112 DOF ($P<.05$). This agrees with reports by Bowling et al. (1977), Wanderstock and Miller (1948), Wheeling et al. (1975), Cross and Smith (1976), and Kropf et al. (1975) who found that forage-fed beef was less desirable in overall acceptability than grain-fed beef. Flavor scores ranged from 3.99 (slight milky oily) for steaks from the 0 DOF cattle to 5.42 (slight beef fat) for steaks from the 112 DOF cattle. Flavor scores for the 56 DOF cattle showed steaks had a more intense beef fat flavor than the 0 DOF cattle ($P<.05$). Likewise, steaks from the 112 DOF steers had a more intense beef fat flavor than steaks from the 56 DOF steers. Steaks from the 0 DOF cattle were less juicy and less tender ($P<.05$) than steaks from either the 56 or 112 DOF steers. The panelists preferred the traditional beef fat flavor over the milky oily grass-fed flavor which was reflected in the overall evaluation. Overall acceptability scores improved significantly from 0 DOF (3.66=moderately undesirable) to 56 DOF (5.11=slightly desirable) ($P<.05$) and from 56 DOF to 112 DOF (5.46=slightly desirable) (P<.05). This concurs with the report of Hedrick et al. (1983) who found that cattle fed grain longer improved in flavor, juiciness, tenderness and overall acceptability.

Table 6 shows the least square means for sensory characteristics of longissimus muscle by pasture type. Appendix C gives the analysis of variance of this data. Pasture type had no effect on any of the sensory parameters. The sensory panelists rated juiciness as "slightly juicy" for steaks from steers from each of the pasture types. Tenderness was rated as "slightly tender" for steaks from each of the pasture types, whereas panelists rated the steaks "slightly milky oily" in flavor. Since the panelists scored steaks as juicy and tender, but rated them as being milky-oily in flavor and slightly undesirable in overall acceptability, flavor seemed to influence overall acceptability scores more than either tenderness or juiciness. Melton et al. (1982b) reported that panelists rated steaks that were milky-oily in flavor more undesirable than steaks that had a grain-fed beef fat flavor. Therefore, feeding to 56 DOF does negate the effect of forage-flavor on palatability. From this data, steers must be fed at least 56 DOF to receive desirable palatability ratings.

IV. DAYS ON FEED AS IT AFFECTS CARCASS CHARACTERISTICS AND CHEMICAL ANALYSIS OF FESCUE-CLOVER BACKGROUNDED CATTLE

Table 7 compares the least square means for carcass traits by DOF for the fescue-clover backgrounded cattle (n=32). The analysis of variance

TABLE 6. LEAST SQUARE MEANS FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM STEERS GROWN ON DIFFERENT PASTURE TYPES

	Pasture type			
Sensory characteristic	Ryegrass	Fescue	Orchardgrass	Fescue-clover
Flavor[b]	4.77[a]	4.82[a]	4.78[a]	4.89[a]
Juiciness[c]	5.12[a]	5.38[a]	5.28[a]	5.16[a]
Tenderness[d]	5.31[a]	5.55[a]	5.56[a]	5.21[a]
Overall acceptability[e]	4.55[a]	4.93[a]	4.71[a]	4.78[a]

[a]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[b]Flavor: 1 = extreme milky oily; 4 = slight milky oily; 8 = extreme beef fat.

[c]Juiciness: 1 = extremely dry; 4 = slightly dry; 8 = extremely juicy.

[d]Tenderness: 1 = extremely tough; 4 = slightly tough; 8 = extremely tender.

[e]Overall acceptability: 1 = extremely undesirable; 4 = slightly undesirable; 8 = extremely desirable.

TABLE 7. LEAST SQUARE MEANS FOR CARCASS TRAITS BY DAYS ON FEED FOR FESCUE-CLOVER BACKGROUNDED STEERS

	Days on feed					
Carcass trait	0	28	56	84	112	140
Hot carcass wt., kg	189.9^{a}	218.9^{b}	241.4^{b}	288.3^{c}	284.8^{c}	324.3^{d}
Adj. fat thickness, mm	1.5^{a}	4.1^{b}	6.6^{b}	9.4^{c}	9.6^{c}	12.4^{d}
Ribeye area, cm^2	59.3^{a}	65.9^{ab}	70.8^{b}	74.8^{c}	72.8^{bc}	83.7^{d}
Yield grade	1.4^{a}	1.7^{a}	1.9^{ab}	2.4^{bc}	2.6^{c}	2.6^{c}
Maturity^{e}	1.4^{a}	1.4^{a}	1.4^{a}	1.4^{a}	1.4^{a}	1.4^{a}
Marbling^{e}	2.9^{a}	3.7^{b}	4.5^{c}	5.8^{d}	5.7^{d}	5.0^{c}
Quality grade^{e}	1.8^{a}	3.2^{b}	5.2^{c}	7.4^{d}	7.2^{d}	6.0^{c}
Lean firmness^{e}	4.0^{a}	5.8^{bc}	6.0^{bc}	6.6^{c}	6.2^{bc}	5.2^{b}
Hindquarter wt., kg	43.9^{a}	54.8^{b}	62.9^{bc}	63.9^{bcd}	65.4^{cd}	74.4^{d}
Round wt., kg	24.6^{a}	25.5^{a}	28.4^{ab}	31.9^{bc}	31.7^{bc}	34.9^{c}
Loin wt., kg	14.3^{a}	18.1^{b}	18.7^{b}	21.7^{c}	22.2^{cd}	24.4^{d}
Flank wt., kg	3.7^{a}	4.3^{ab}	5.2^{b}	6.5^{c}	6.6^{c}	8.9^{d}
Cod wt., kg	0.4^{a}	0.5^{a}	0.8^{ab}	0.6^{a}	1.3^{c}	1.1^{bc}
Kidney fat wt., %	1.0^{a}	1.4^{a}	2.3^{b}	2.3^{b}	2.6^{bc}	3.1^{c}
Femur wt., kg	2.0^{a}	1.8^{a}	1.8^{a}	2.0^{a}	2.0^{a}	1.9^{a}
Femur length, cm	37.7^{a}	37.3^{a}	37.2^{a}	38.0^{a}	37.7^{a}	38.0^{a}
Biceps femoris wt., kg	3.9^{a}	4.3^{a}	4.6^{ab}	5.2^{b}	5.3^{b}	5.5^{b}
Biceps femoris area, cm^2	96.1^{a}	107.0^{ab}	113.8^{ab}	121.2^{b}	119.2^{b}	116.2^{b}

^{abcd}Least square means in the same row bearing different superscript letters differ ($P<.05$).
^{e}Refer to Table 1 for legend.

for this data is given in Appendix D. Hot carcass weight increased ($P<.05$) as DOF increased. Dinius and Cross (1978) also reported that increased length of grain feeding increased carcass weight ($P<.05$). The 0 DOF steers were lighter in carcass weight ($P<.05$) than any other DOF groups. Carcasses of the 28 and 56 DOF steers were lighter ($P<.05$) than the 84, 112 and 140 DOF steers. Also, the 140 DOF cattle had heavier ($P<.05$) carcasses than any other feeding groups. Adjusted fat thickness and ribeye area increased ($P<.05$) with days on feed. An increase in fat thickness as DOF increased caused a corresponding increase in numerical USDA yield grade. The yield grades for the 84, 112 and 140 DOF cattle were not different ($P>.05$) from each other although the 140 DOF steers had carcasses with more external fat thickness. This occurred because the 84 and 112 DOF groups received little adjustment for ribeye area compared to carcass weight, whereas the 140 DOF cattle received a more substantial adjustment for ribeye area. Maturity score did not change across DOF. All DOF groups were within the USDA A maturity group. Marbling scores varied across DOF from Practically Devoid^{80} for the 0 DOF cattle to Small^{0} for the 140 DOF cattle. This is in agreement with Harrison et al. (1978) who reported that increased length of feeding resulted in a corresponding increase in marbling scores. Likewise, quality grade improved from 0 to 84 DOF but declined from 112 to 140 DOF. One possible explanation for the decline in marbling score and quality grade from 112 to 140 DOF may have been due to the time of year the steers were slaughtered. The 140 DOF steers were slaughtered in the month of January. They may have experienced harsh weather that resulted in preslaughter stress and the depletion of intramuscular fat. Muscle from the 140 DOF cattle was firmer ($P<.05$) than for the 0 DOF cattle. Muscle firmness tended to be closely related to marbling score. Results of this study suggest that intramuscular fat protected the longissimus muscle and provided added support. Even though changes in muscle firmness paralleled changes in marbling score, after 28 DOF lean firmness did not improve. Hindquarter weights, round weights, loin weights, flank weights, cod fat weights, and kidney fat weights all increased ($P<.05$) as DOF increased from 0 to 140 DOF.

Femur weights and lengths were not different across DOF (Table 7). Biceps femoris areas were influenced by length of feeding. They increased from 96.10 cm^2 for the 0 DOF steers to 116.2 cm^2 for the 140 DOF steers ($P<.05$).

Table 8 contains the least square means for chemical and physical characteristics of longissimus muscle by days on feed for the fescue-clover backgrounded cattle. Appendix E shows the analysis of variance for this data. Moisture percentage decreased and fat percentage tended to increase on a raw weight basis, but was not significant ($P>.05$) as DOF increased. The moisture content was also lower in cooked steaks from 84 DOF steers compared to 56 DOF steers ($P<.05$). Lipid percentage was lower in cooked steaks from the 0 and 28 DOF steers than from steers fed past 84 DOF ($P<.05$). The 84 DOF steers had more percentage lipid of the cooked steaks than the 0, 28 and 56 DOF groups ($P<.05$). This parallels an increase in marbling score. Marbling score was lower for carcasses from the 0 and 28 DOF steers than for the 84 DOF steers ($P<.05$). The moisture content was lower in cooked steaks from the 84 and 112 DOF steers than from the 28 DOF steers. No trend was noted in non-volatile cooking loss percentage across DOF; however, the 0, 84 and 112 DOF groups had less non-volatile cooking loss ($P<.05$) than the 28 and 140 DOF groups. In contrast to the

TABLE 8. LEAST SQUARE MEANS FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE BY DAYS ON FEED FOR FESCUE-CLOVER BACKGROUNDED STEERS

	Days on feed					
Dependent variable	0	28	56	84	112	140
Moisture, raw, %	75.15^{bc}	76.81^{c}	74.54^{ab}	73.46^{ab}	73.84^{ab}	72.96^{a}
Moisture, cooked, %	66.06^{abc}	67.84^{c}	67.22^{bc}	63.88^{a}	65.35^{ab}	65.66^{abc}
Fat, raw, %^{d}	2.92^{a}	2.36^{a}	3.52^{a}	4.21^{a}	4.07^{a}	4.26^{a}
Fat, cooked, %^{d}	3.66^{a}	3.88^{a}	5.49^{ab}	8.27^{c}	7.28^{bc}	7.08^{bc}
Non-volatile cook loss, %	6.55^{ab}	8.04^{c}	7.69^{bc}	6.11^{a}	5.78^{a}	7.97^{c}
Total cooking loss, %	20.78^{a}	21.57^{a}	20.27^{a}	19.59^{a}	19.24^{a}	20.60^{a}
Soluble collagen, mg/g	2.58^{a}	2.54^{a}	2.51^{a}	1.60^{a}	1.58^{a}	1.42^{a}
Insoluble collagen, mg/g	2.04^{a}	5.33^{b}	4.48^{ab}	3.47^{ab}	3.90^{ab}	3.62^{ab}
Total collagen, mg/g	4.62^{a}	7.87^{a}	6.99^{a}	5.07^{a}	5.48^{a}	5.04^{a}
Soluble collagen, %	44.67^{a}	32.80^{a}	37.52^{a}	29.66^{a}	30.23^{a}	30.42^{a}
Insoluble collagen, %	55.33^{a}	67.20^{a}	62.48^{a}	70.34^{a}	69.77^{a}	69.58^{a}
Warner-Bratzler, kg	4.52^{c}	3.31^{ab}	3.43^{ab}	2.43^{a}	3.67^{bc}	3.56^{bc}

^{abc}Least square means in the same row bearing different superscript letters differ ($P<.05$).
^{d}Wet weight basis

comparison for cattle fed for 0, 56 and 112 DOF (Table 3), no evidence of composition of total cooking loss could be discerned. Total cooking loss percentage did not vary as DOF increased. Soluble collagen was not different across DOF, but muscles from the 28 DOF steers had more insoluble collagen than muscle from the 0 DOF steers (5.33 mg/g and 2.04 mg/g, respectively). Total collagen did not vary from 0 DOF to 140 DOF. Soluble collagen percentage ranged from 29.66% to 44.67% and insoluble collagen percentage ranged from 55.33% to 70.34%. There tended to be a decrease in percentage of soluble and an increase in insoluble collagen percentage as the cattle grew older, but no differences were statistically significant ($P>.05$).

The 0 DOF steers were less tender ($P<.05$) in Warner-Bratzler shear force than the 28, 56 and 84 DOF steers (Table 8). The 84 DOF steers were lowest in Warner-Bratzler shear force and were statistically different from the 0, 112 and 140 DOF groups ($P<.05$). Warner-Bratzler shear force tended to decrease up to 84 DOF then increased up to 140 DOF. The sensory panelists agreed with the Warner-Bratzler shear findings. Panelists found that steaks became more tender up to 84 DOF then became less tender from 84 to 140 DOF.

V. DAYS ON FEED AS IT AFFECTS SENSORY CHARACTERISTICS OF BEEF LONGISSIMUS MUSCLE OF FESCUE-CLOVER BACKGROUNDED CATTLE

Table 9 contains the least square means for sensory characteristics of longissimus muscle by DOF for fescue-clover backgrounded steers. The analysis of variance for this data is given in Appendix F. Flavor scores

TABLE 9. LEAST SQUARE MEANS FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE BY DAYS ON FEED FOR FESCUE-CLOVER BACKGROUNDED STEERS

	Days on feed					
Dependent variable	0	28	56	84	112	140
Flavor[e]	4.24^{a}	4.65^{ab}	5.08^{bcd}	5.40^{d}	5.27^{cd}	4.87^{bc}
Juiciness[f]	4.41^{a}	5.15^{b}	5.38^{bc}	5.65^{c}	5.52^{bc}	5.80^{c}
Tenderness[g]	4.24^{a}	5.59^{b}	5.53^{b}	6.20^{c}	5.56^{b}	5.51^{b}
Overall acceptability[h]	3.73^{a}	4.69^{b}	5.16^{bc}	5.72^{d}	5.22^{c}	5.16^{bc}

[abc]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[e]Flavor: 1 = extreme milky oily; 4 = slight milky oily; 8 = extreme beef fat.

[f]Juiciness: 1 = extremely dry; 4 = slightly dry; 8 = extremely juicy.

[g]Tenderness: 1 = extremely tough; 4 = slightly tough ; 8 = extremely tender.

[h]Overall acceptability: 1 = extremely undesirable; 4 = slightly undesirable; 8 = extremely desirable.

tended to increase from 0 to 140 DOF. Flavor scores ranged from 4.24 (slight milky oily) for the 0 DOF steers to 5.27 (slight beef fat) for the 112 DOF steers. The 0 DOF group was ranked more milky oily in flavor than steers fed beyond 56 DOF (P<.05). Beyond 56 DOF, little difference in flavor was observed. Flavor scores tended to follow percentage fat found in the muscle. As the percentage fat increased, milky oily flavor decreased.

Juiciness scores also tended to increase with DOF (Table 9). The 0 DOF steaks were ranked less juicy than any of the other treatments (P<.05). Likewise, juiciness ratings followed the same trend as the flavor scores and percentage fat.

Tenderness ratings increased up to 84 DOF (became more tender) then declined to 140 DOF (Table 9). The 0 DOF steers were scored tougher than any other treatment. The 84 DOF group received the most favorable tenderness ratings and were different from all other DOF groups (P<.05). Sensory panel ratings for tenderness tended to follow the same trend as the percentage insoluble collagen.

Sensory panelists considered the 0 DOF steers to be more unacceptable in overall desirability than any other DOF group (Table 9) (P<.05). Overall acceptability scores followed the same trend as flavor and juiciness scores. An increase in overall acceptability was observed from 0 DOF up to 140 DOF. Overall acceptability became desirable at 56 DOF.

VI. CARCASS, CHEMICAL AND PHYSICAL CHARACTERISTICS OF ANGUS, HEREFORD AND ANGUS X HERFORD STEERS

Table 10 shows the least square means for carcass traits of Angus, Hereford and Angus X Hereford (AXH) cross steers. Appendix G shows the analysis of variance for these characteristics. There was no difference among the Angus, Hereford and AXH steers for HCW. The Angus steers tended to have a lower adjusted fat thickness (.8 mm) as compared to the Hereford (1.0 mm) and AXH steers (.9 mm) but the differences were not significant (P>.05). The Hereford steers had larger ribeye areas than the Angus steers (P<.05) but were not different from the AXH cross steers (P>.05). USDA yield grade, maturity, marbling score and final USDA quality grade did not differ for any of the three groups (P>.05). None of the weights for hindquarter, round, loin, flank, cod fat, kidney fat, femur or biceps femoris differed for any of the breeds(P>.05). Neither did the femur length or the biceps femoris area (P>.05).

Table 11 displays the least square means for chemical and physical characteristics of the longissimus muscle for Angus, Hereford and AXH cross steers. Appendix H shows the analysis of variance for this data. No difference was noticed for any of the chemical or physical parameters among any of the breeds. Since Angus, Hereford and the resulting cross are similar in maturity pattern, it is expected that little difference be found in the composition of the carcasses. Prior et al. (1977) found that small framed cattle deposit fat at similar rates.

TABLE 10. LEAST SQUARE MEANS FOR CARCASS TRAITS OF ANGUS, HEREFORD AND ANGUS X HEREFORD STEERS

	Sire type		
Carcass characteristic	Angus	Hereford	AngusXHereford
Hot carcass wt., kg	233.6[a]	253.6[a]	240.4[a]
Adj. fat thickness, mm	0.8[a]	1.0[a]	0.9[a]
Ribeye area, cm^2	65.0[a]	73.1[b]	68.2[ab]
Yield grade	2.3[a]	2.7[a]	2.4[a]
Maturity[c]	1.4	1.4[a]	1.4[a]
Marbling[d]	4.2	4.4[a]	4.3[a]
Quality grade[e]	4.5[a]	4.9[a]	4.6[a]
Lean firmness[f]	5.4[a]	5.1[a]	4.7[a]
Hindquarter wt., kg	54.7[a]	58.3[a]	55.5[a]
Round wt., kg	27.0[a]	28.2[a]	27.6[a]
Loin wt., kg	17.9[a]	19.6[a]	18.7[a]
Flank wt., kg	5.6[a]	5.7[a]	5.7[a]
Cod wt., kg	0.8[a]	0.9[a]	1.0[a]
Kidney fat wt., %	2.0[a]	2.1[a]	2.0[a]
Femur wt., kg	1.7[a]	1.7[a]	1.8[a]
Femur length, cm	36.0[a]	36.3[a]	36.1[a]
Biceps femoris wt., kg	4.3[a]	4.7[a]	4.4[a]
Biceps femoris area, cm^2	104.2[a]	113.6[a]	106.3[a]

[ab]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[c]Maturity: 1.0 = A^0; 1.2 = A^{20}; 1.4 = A^{40}.

[d]Marbling: 1 = devoid; 5 = small; 10 = abundant.

[e]Quality grade: 1 = low standard; 6 = high select; 12 = high prime.

[f]Lean firmness: 1 = very soft; 5 = slightly firm; 8 = very firm.

TABLE 11. LEAST SQUARE MEANS FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE FOR ANGUS, HEREFORD AND ANGUS X HEREFORD STEERS

	Sire type		
Dependent variable	Angus	Hereford	AngusXHereford
Moisture, raw, %	74.64[a]	74.91[a]	74.25[a]
Moisture, cooked, %	65.71[a]	65.20[a]	65.00[a]
Fat, raw, %[b]	3.65[a]	3.37[a]	3.04[a]
Fat, cooked, %[b]	5.44[a]	6.22[a]	6.51[a]
Volatile cooking loss, %	13.79[a]	12.54[a]	13.88[a]
Non-volatile cook loss, %	6.64[a]	7.01[a]	7.04[a]
Total cooking loss, %	20.43[a]	19.41[a]	20.93[a]
Soluble collagen, mg/g	2.88[a]	1.82[a]	2.67[a]
Insoluble collagen, mg/g	3.63[a]	3.38[a]	2.91[a]
Total collagen, mg/g	6.51[a]	5.20[a]	5.58[a]
Soluble collagen, %	44.06[a]	34.48[a]	43.01[a]
Insoluble collagen, %	55.94[a]	65.52[a]	56.99[a]
Warner-Bratzler, kg	3.89[a]	3.60[a]	3.87[a]

[a]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[b]Wet weight basis.

VII. SENSORY CHARACTERISTICS OF ANGUS, HEREFORD AND ANGUS X HERFORD STEERS

Table 12 contains the least square means for sensory characteristics of the longissimus muscle for Angus, Hereford and AXH cross steers. Appendix I shows the analysis of variance for the sensory characteristics. The Hereford steers were significantly stronger in beef fat flavor (5.11) than either the Angus (4.74) or the AXH cross steers (4.49). There was no difference among any of the three groups, for juiciness, tenderness, and overall acceptability.

TABLE 12. LEAST SQUARE MEANS FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE FOR ANGUS, HEREFORD AND ANGUS X HEREFORD STEERS

	Sire type		
Sensory characteristic	Angus	Hereford	AngusXHereford
Flavor[c]	4.74[a]	5.11[b]	4.49[a]
Juiciness[d]	5.05[a]	5.29[a]	5.04[a]
Tenderness[e]	5.10[a]	5.13[a]	5.12[a]
Overall acceptability[f]	4.51[a]	4.87[a]	4.39[a]

[ab]Least square means in the same row bearing different superscript letters differ ($P<.05$).

[c]Flavor: 1 = extreme milky oily; 4 = slight milky oily; 8 = extreme beef fat.

[d]Juiciness: 1 = extremely dry; 4 = slightly dry; 8 = extremely juicy.

[e]Tenderness: 1 = extremely tough; 4 = slightly tough; 8 = extremely tender.

[f]Overall acceptability: 1 = extremely undesirable; 4 = slightly undesirable; 8 = extremely desirable.

CHAPTER V

CONCLUSIONS

The objective of this study was to determine the effects of length of grain feeding and pasture type on carcass and sensory characteristics, and on chemical composition of muscle.

Angus, Hereford, Angus X Hereford and crossbred steers were backgrounded over winter from November to July and August, then placed on a high concentrate diet. The pasture types included ryegrass, Kentucky 31 Fescue, orchardgrass and fescue-clover mixed pastures. All four pasture types had length of grain feeding of 0, 56 and 112 days on feed (DOF), with the fescue-clover backgrounded cattle having additional grain feeding periods of 28, 84 and 140 DOF.

Carcass, sensory and chemical characteristics were affected more by DOF than by pasture type. Carcass quality grade improved with DOF. Conversely, carcass yield grade was inferior for the longer fed cattle. Weights of the various primal cuts were influenced with DOF. All increased linearly with DOF. Flavor and overall acceptability scores increased significantly from 0 to 56 DOF, and from 56 to 112 DOF. Sensory panel ratings for tenderness and juiciness improved significantly only from 0 to 56 DOF. Therefore, results of this study would indicate that steers need to be fed a minimum of 112 DOF to impart acceptable flavor, juiciness, tenderness and overall acceptability.

Total collagen content did not vary across DOF. Collagen content had little relationship to sensory panel evaluated tenderness. Warner-Bratzler shear force and sensory panel evaluated tenderness were more closely related. Both the Warner-Bratzler shear and sensory panel ratings for tenderness indicated that steaks became more tender from 0 to 56 DOF.

Warner-Bratzler shear force values were obtained for medial, center and lateral sections of the loin steaks. Warner-Bratzler shear force data from the 0, 56 and 112 DOF cattle were pooled. Shear force values for the cores taken from the center of the steaks were lower ($P<.05$) than shear force values for cores taken from the medial and lateral sections.

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APPENDIXES

APPENDIX A. ANALYSIS OF VARIANCE FOR CARCASS TRAITS OF STEERS FED GRAIN 0, 56 OR 112 DAYS

Dependent variable	df	SS	P > F
Hot carcass wt., kg			
DOF[a]	2	688684	.0001
Pasture type[b]	3	45922	.0028
Error	63	184468	
Total	68	924602	
Adjusted fat thickness, mm			
DOF	2	.91	.0001
Pasture type	3	.31	.0001
Error	63	.55	
Total	68	1.81	
Ribeye area, cm^2			
DOF	2	96.84	.0001
Pasture type	3	1.20	.8053
Error	63	76.93	
Total	68	175.53	
Kidney pelvic and heart fat, %			
DOF	2	9.09	.0001
Pasture type	3	1.06	.0328
DOF*Pasture type[c]	6	3.10	.0007
Error	57	6.44	
Total	68	19.87	
Yield grade			
DOF	2	10.62	.0001
Pasture type	3	3.61	.0007
Error	63	11.72	
Total	68	26.30	
Maturity			
DOF	2	0.01	.3844
Pasture type	3	0.03	.0352
Error	63	0.20	
Total	68	0.23	
Marbling			
DOF	2	193.75	.0001
Pasture type	3	4.93	.3122
Error	63	85.33	
Total	68	284.20	

APPENDIX A (Continued)

Dependent variable	df	SS	P > F
Quality grade			
DOF	2	193.76	.0001
Pasture type	3	4.93	.3122
Error	63	85.33	
Total	68	284.20	
Lean firmness			
DOF	2	17.36	.0005
Pasture type	3	6.06	.1245
Error	63	64.01	
Total	68	87.76	
Lean color			
DOF	2	0.34	.7626
Pasture type	3	6.13	.0266
DOF*Pasture type	6	9.90	.0239
Error	57	35.30	
Total	68	51.74	
Lean texture			
DOF	2	32.66	.0001
Pasture type	3	11.43	.0120
DOF*Pasture type	6	12.99	.0497
Error	57	54.43	
Total	68	111.77	
Hindquarter wt., kg			
DOF	2	35007.04	.0001
Pasture type	3	2268.03	.0358
Error	63	15714.09	
Total	68	52979.70	
Round wt., kg			
DOF	2	5621.04	.0001
Pasture type	3	349.31	.1013
Error	63	3392.35	
Total	68	9378.72	
Loin wt., kg			
DOF	2	4459.77	.0001
Pasture type	3	482.20	.0004
Error	63	1460.44	
Total	68	6429.94	

APPENDIX A (Continued)

Dependent variable	df	SS	P > F
Flank wt., kg			
DOF	2	403.44	.0001
Pasture type	3	64.45	.0031
Error	63	250.90	
Total	68	739.12	
Kidney fat wt., %			
DOF	2	468.40	.0001
Pasture type	3	10.68	.2369
Error	63	154.73	
Total	68	638.57	
Cod wt., kg			
DOF	2	26.47	.0001
Pasture type	3	17.56	.0001
Error	63	39.90	
Total	68	84.32	
Femur wt., kg			
DOF	2	1.53	.0800
Pasture type	3	1.11	.2918
Error	63	18.42	
Total	68	21.04	
Femur length, cm			
DOF	2	7.11	.0004
Pasture type	3	2.53	.1109
Error	63	25.47	
Total	68	34.93	
Biceps femoris wt., kg			
DOF	2	134.03	.0001
Pasture type	3	12.42	.0403
Error	63	87.53	
Total	68	233.78	

APPENDIX A (Continued)

Biceps femoris area, cm^2			
DOF	2	179.28	.0001
Pasture type	3	61.61	.0025
Error	63	238.72	
Total	68	478.07	

[a]DOF = Days on feed.

[b]Pasture type included ryegrass, Kentucky 31 Fescue, orchardgrass and fescue mixed with clover pastures.

[c]DOF*Pasture type = Days on feed interaction with pasture type.

APPENDIX B. ANALYSIS OF VARIANCE FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM STEERS FED GRAIN 0, 56 OR 112 DAYS

Dependent variable	df	SS	P > F
Moisture, raw %			
DOF[a]	2	59.05	.0004
Pasture type[b]	3	19.21	.1270
Error	63	170.79	
Total	68	243.82	
Moisture, cooked, %			
DOF	2	19.54	.0570
Pasture type	3	10.62	.3608
Error	63	198.52	
Total	68	228.61	
Fat, raw wet wt., %			
DOF	2	49.94	.0002
Pasture type	3	2.43	.7991
Error	63	127.74	
Total	68	179.17	
Fat, cooked, wet wt., %			
DOF	2	97.63	.0001
Pasture type	3	14.12	.0028
Error	63	181.48	
Total	68	291.75	
Volatile cooking loss, %			
DOF	2	19.74	.3189
Pasture type	3	7.36	.8326
DOF*Pasture type[c]	6	121.26	.0398
Error	57	482.53	
Total	68	628.61	
Non-volatile cooking loss, %			
DOF	2	10.29	.0564
Pasture type	3	5.35	.3798
Error	63	107.73	
Total	68	123.05	
Total cooking loss, %			
DOF	2	49.19	.1047
Pasture type	3	14.02	.7220
Error	63	662.44	
Total	68	724.42	

APPENDIX B (Continued)

Dependent variable	df	SS	P > F
Soluble collagen, mg/g			
DOF	2	12.49	.0861
Pasture type	3	6.54	.4472
Error	49	118.63	
Total	54	138.18	
Insoluble collagen, mg/g			
DOF	2	10.58	.0893
Pasture type	3	4.22	.5717
Error	49	102.17	
Total	54	118.81	
Soluble collagen, %			
DOF	2	1637.99	.0929
Pasture type	3	2209.48	.0949
Error	49	16081.60	
Total	54	20163.46	
Insoluble collagen, %			
DOF	2	1637.99	.0929
Pasture type	3	2209.49	.0949
Error	49	16081.60	
Total	54	20163.50	
Total collagen mg/g			
DOF	2	14.58	.1961
Pasture type	3	2.74	.8882
Error	49	212.17	
Total	54	229.45	
Warner-Bratzler shear			
DOF	2	89.10	.0001
Pasture type	3	3.86	.6927
Error	49	113.39	
Total	54	205.97	

[a]DOF = Days on feed.

[b]Pasture type included ryegrass, Kentucky 31 Fesque, orchardgrass and fescue mixed with clover pastures.

[c]DOF*Pasture type = Days on feed interaction with pasture type.

APPENDIX C. ANALYSIS OF VARIANCE FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE OF STEERS FED GRAIN 0, 56 OR 112 DAYS

Dependent variable	df	SS	P > F
Flavor			
DOF[a]	2	192.64	.0001
Pasture type[b]	3	1.19	.9086
Day[c]	14	47.13	.0927
Error	608	1331.29	
Total	627	1566.11	
Juiciness			
DOF	2	110.18	.0001
Pasture type	3	5.51	.4508
Day	14	67.97	.0040
Error	608	1269.92	
Total	627	1437.11	
Tenderness			
DOF	2	172.82	.0001
Pasture type	3	12.57	.1272
Day	14	60.23	.0189
Error	608	1336.10	
Total	627	1577.07	
Overall acceptability			
DOF	2	318.12	.0001
Pasture type	3	9.56	.2638
Day	14	99.47	.0002
Error	608	1457.83	
Total	627	1873.72	

[a]DOF = Days on feed.

[b]Pasture type included ryegrass, Kentucky 31 Fescue, orchardgrass and fescue mixed with clover pastures.

[c]Day is the blocking variable for the day each steak was served.

APPENDIX D. ANALYSIS OF VARIANCE FOR CARCASS TRAITS OF FESCUE-CLOVER BACKGROUNDED CATTLE

Dependent variable	df	SS	P > F
Hot carcass wt., kg			
DOF[a]	5	331388	.0001
Error	25	64098	
Total	30	395486	
Adjusted fat thickness, mm			
DOF	5	.68	.0001
Error	25	.16	
Total	30	.84	
Ribeye area, cm^2			
DOF	5	44.86	.0001
Error	25	21.85	
Total	30	66.72	
Kidney pelvic and heart fat, %			
DOF	5	4.35	.0001
Error	25	1.04	
Total	30	5.39	
Yield grade			
DOF	5	7.21	.0001
Error	25	4.65	
Total	30	11.86	
Maturity			
DOF	5	.01	.6262
Error	25	.04	
Total	30	.05	
Marbling			
DOF	5	36.16	.0001
Error	25	6.77	
Total	30	42.92	

APPENDIX D (Continued)

Dependent variable	df	SS	P > F
Quality grade			
DOF	5	138.50	.0001
Error	25	18.47	
Total	30	156.97	
Lean firmness			
DOF	5	23.77	.0004
Error	25	17.58	
Total	30	41.35	
Lean color			
DOF	5	5.22	.2311
Error	25	17.62	
Total	30	22.84	
Lean texture			
DOF	5	40.85	.0001
Error	25	11.08	
Total	30	51.94	
Hindquarter wt., kg			
DOF	5	14658.28	.0001
Error	25	9253.25	
Total	30	23911.53	
Round wt., kg			
DOF	5	2144.43	.0001
Error	25	1449.29	
Total	30	3593.72	
Loin wt., kg			
DOF	5	17581.34	.0001
Error	25	399.77	
Total	30	2158.10	

APPENDIX D (Continued)

Dependent variable	df	SS	P > F
Flank wt., kg			
DOF	5	459.85	.0001
Error	25	100.77	
Total	30	560.62	
Kidney fat wt., %			
DOF	5	304.83	.0001
Error	25	59.58	
Total	30	364.40	
Cod wt., kg			
DOF	5	15.07	.0003
Error	25	11.48	
Total	30	26.54	
Femur wt., kg			
DOF	5	.67	.5443
Error	25	4.34	
Total	30	5.02	
Femur length, cm			
DOF	5	.45	.8839
Error	25	6.88	
Total	30	7.33	
Biceps femoris wt., kg			
DOF	5	52.26	.0007
Error	25	41.47	
Total	30	93.73	
Biceps femoris area, cm^2			
DOF	5	58.41	.0594
Error	25	118.02	
Total	30	176.43	

[a]DOF = Days on feed.

APPENDIX E. ANALYSIS OF VARIANCE FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM FESCUE-CLOVER BACKGROUNDED STEERS

Dependent variable	df	SS	P > F
Moisture, raw %			
DOF[a]	5	35.60	.0144
Error	25	35.90	
Total	30	68.50	
Moisture, cooked, %			
DOF	5	52.82	.0329
Error	25	90.51	
Total	30	143.33	
Fat, raw wet wt., %			
DOF	5	11.63	.2136
Error	25	26.34	
Total	30	37.96	
Fat, cooked, wet wt., %			
DOF	5	95.05	.0002
Error	25	61.26	
Total	30	156.31	
Volatile cooking loss, %			
DOF	5	24.65	.0220
Error	25	40.04	
Total	30	64.69	
Non-volatile cooking loss, %			
DOF	5	26.18	.0019
Error	25	26.09	
Total	30	52.26	
Total cooking loss, %			
DOF	5	19.39	.4536
Error	25	103.81	
Total	30	123.20	

APPENDIX E (Continued)

Dependent variable	df	SS	P > F
Soluble collagen, mg/g			
DOF	5	6.50	.3303
Error	20	21.08	
Total	25	27.58	
Insoluble collagen, mg/g			
DOF	5	19.68	.2568
Error	20	55.07	
Total	25	74.74	
Soluble collagen, %			
DOF	5	481.48	.6664
Error	20	2973.05	
Total	25	3454.53	
Insoluble collagen, %			
DOF	5	481.48	.6664
Error	20	2973.05	
Total	25	3454.53	
Total collagen mg/g			
DOF	5	35.50	.2398
Error	20	95.81	
Total	25	131.31	
Warner-Bratzler shear			
DOF	5	32.90	.0229
Error	20	19.75	
Total	25	52.65	

[a]DOF = Days on feed.

APPENDIX F. ANALYSIS OF VARIANCE FOR SENSORY CHARACTERISTICS OF BEEF LONGISSIMUS MUSCLE FOR FESCUE-CLOVER BACKGROUNDED CATTLE

Dependent variable	df	SS	P > F
Flavor			
DOF[a]	5	259.36	.0001
Day[b]	14	39.75	.2040
Error	1051	2306.22	
Total	1070	2597.86	
Juiciness			
DOF	5	163.65	.0001
Day	14	99.28	.0001
Error	1051	288.87	
Total	1070	2363.39	
Tenderness			
DOF	5	306.46	.0001
Day	14	113.88	.0001
Error	1051	2508.96	
Total	1070	2959.62	
Overall acceptability			
DOF	5	448.69	.0001
Day	14	116.52	.0001
Error	1050	2459.03	
Total	1070	3040.18	

[a]DOF = Days on feed.

[b]Day is the blocking variable for the day each steak was served.

APPENDIX G. ANALYSIS OF VARIANCE FOR CARCASS TRAITS OF ANGUS, HEREFORD AND ANGUS X HEREFORD STEERS

Dependent variable	df	SS	P > F
Hot carcass wt., kg			
Sire type[a]	2	11154	.6147
Error	41	464399	
Total	43	475553	
Adjusted fat thickness, mm			
Sire type	2	0.04	.4801
Error	41	1.16	
Total	43	1.20	
Ribeye area, cm^2			
Sire type	2	9.06	.1181
Error	41	82.08	
Total	43	91.09	
Kidney pelvic and heart fat, %			
Sire type	2	0.02	.9326
Error	41	7.40	
Total	43	7.42	
Yield grade			
Sire type	2	0.04	.9414
Error	41	14.08	
Total	43	14.12	
Maturity			
Sire type	2	0.01	.6420
Error	41	0.15	
Total	43	0.16	
Marbling			
Sire type	2	0.12	.9265
Error	41	31.53	
Total	43	31.65	
Quality grade			
Sire type	2	0.87	.8902
Error	41	152.04	
Total	43	152.91	

APPENDIX G (Continued)

Dependent variable	df	SS	P > F
Lean firmness			
Sire type	2	3.26	.2961
Error	41	53.29	
Total	43	56.55	
Lean color			
Sire type	2	0.55	.7392
Error	41	37.00	
Total	43	37.55	
Lean texture			
Sire type	2	1.12	.7165
Error	41	68.04	
Total	43	69.16	
Hindquarter wt., kg			
Sire type	2	350.21	.7893
Error	41	30164.89	
Total	43	30515.10	
Round wt., kg			
Sire type	2	43.01	.8142
Error	41	4267.72	
Total	43	4310.73	
Loin wt., kg			
Sire type	2	88.33	.5942
Error	41	3434.28	
Total	43	3522.62	
Flank wt., kg			
Sire type	2	0.59	.9768
Error	41	474.75	
Total	43	475.34	
Kidney fat wt., %			
Sire type	2	3.93	.7964
Error	41	352.26	
Total	43	356.19	
Cod wt., kg			
Sire type	2	0.91	.6663
Error	41	45.39	
Total	43	46.30	

APPENDIX G (Continued)

Dependent variable	df	SS	P > F
Femur wt., kg			
Sire type	2	0.24	.3240
Error	41	4.22	
Total	43	4.46	
Femur length, cm			
Sire type	2	0.10	.7661
Error	41	7.89	
Total	43	7.99	
Biceps femoris wt., kg			
Sire type	2	3.56	.5285
Error	41	109.75	
Total	43	113.31	
Biceps femoris area, cm^2			
Sire type	2	12.05	.3551
Error	41	226.77	
Total	43	238.81	

[a]Sire type = Angus, Hereford and A X H cross steers.

APPENDIX H. ANALYSIS OF VARIANCE FOR CHEMICAL AND PHYSICAL CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM ANGUS, HEREFORD AND ANGUS X HERFORD STEERS

Dependent variable	df	SS	P > F
Moisture, raw %			
Sire type[a]	2	1.46	.8560
Error	41	154.07	
Total	43	155.53	
Moisture, cooked, %			
Sire type	2	3.73	.5850
Error	41	133.63	
Total	43	137.35	
Fat, raw wet wt., %			
Sire type	2	2.12	.7222
Error	41	105.68	
Total	43	107.78	
Fat, cooked, wet wt., %			
Sire type	2	8.86	.2331
Error	41	114.21	
Total	43	123.07	
Volatile cooking loss, %			
Sire type	2	9.60	.1531
Error	41	97.56	
Total	43	107.16	
Non-volatile cooking loss, %			
Sire type	2	1.51	.6879
Error	41	79.94	
Total	43	81.45	
Total cooking loss, %			
Sire type	2	9.31	.3479
Error	41	171.66	
Total	43	180.96	

APPENDIX H (Continued)

Dependent variable	df	SS	P > F
Soluble collagen, mg/g			
Sire type	2	5.24	.4040
Error	41	89.91	
Total	43	95.15	
Insoluble collagen, mg/g			
Sire type	2	3.23	.5060
Error	41	74.20	
Total	43	77.43	
Soluble collagen, %			
Sire type	2	432.72	.5909
Error	41	12944.00	
Total	43	13376.72	
Insoluble collagen, %			
Sire type	2	432.72	.5909
Error	41	12944.00	
Total	43	13376.72	
Total collagen mg/g			
Sire type	2	10.63	.3048
Error	41	137.91	
Total	43	148.54	
Warner-Bratzler shear			
Sire type	2	2.32	.7792
Error	41	184.53	
Total	43	186.84	

[a]Sire type = Angus, Hereford and A X H cross steers.

APPENDIX I. ANALYSIS OF VARIANCE FOR SENSORY CHARACTERISTICS OF LONGISSIMUS MUSCLE FROM ANGUS, HEREFORD AND ANGUS X HERFORD STEERS

Dependent variable	df	SS	P > F
Flavor			
Sire type[a]	2	19.62	.0217
Error	546	1388.19	
Total	548	1407.81	
Juiciness			
Sire type	2	4.37	.3918
Error	546	1271.43	
Total	548	1275.80	
Tenderness			
Sire type	2	0.10	.9840
Error	546	1646.13	
Total	548	1646.22	
Overall acceptability			
Sire type	2	12.06	.1296
Error	546	1605.91	
Total	548	1617.97	

[a]Sire type = Angus, Hereford and A X H cross steers.

VITA

Fred William Pohlman was born October 28, 1964 to Mr. and Mrs. Delmar Pohlman of Missouri. He graduated from Oak Ridge R-6 High School in May of 1983. In the fall of 1983 he enrolled at Southeast Missouri State University in Cape Girardeau, Missouri. He then transferred to the University of Missouri-Columbia where he received his Bachelor of Science degree in Agriculture, with emphasis in Animal Science in May 1987. In July 1987 he enrolled in the graduate school of the University of Tennessee-Knoxville. While working towards a Master of Science degree in Food Technology and Science, he held the position of graduate research assistant in the Department of Food Technology and Science. He is a member of the American Society of Animal Science, American Meat Science Association, and Gamma Sigma Delta.