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Effect of Forage Feeding and Length of Grain Finishing Period on Selected Performance, Carcass, and Sensory Characteristics of Serially Slaughtered Hereford Steers of Varying Frame Score Classifications

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To the Graduate Council:

I am submitting herewith a thesis written by Henry Walker Stockley III entitled "Effect of Forage Feeding and Length of Grain Finishing Period on Selected Performance, Carcass, and Sensory Characteristics of Serially Slaughtered Hereford Steers of Varying Frame Score Classifications." I have examined the final electronic 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 Science and Technology.

James Riemann, Major Professor

We have read this thesis and recommend its acceptance:

Sharon L. Melton, Curtis C. Melton, & W.R. Backus

Accepted for the Council:

Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
To the Graduate Council:

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Wm. R. Backus

Accepted for the Council:

Lawrence Minkel
Vice Chancellor
Graduate Studies and Research
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ON SELECTED PERFORMANCE, CARCASS, AND SENSORY
CHARACTERISTICS OF SERIALLY SLAUGHTERED
HEREFORD STEERS OF VARYING FRAME
SCORE CLASSIFICATIONS

A Thesis
Presented for the
Master of Science
Degree
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Henry Walker Stockley, III
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ABSTRACT

Eighty-one Hereford steers were backgrounded on fescue-orchard grass-clover pasture and then removed after summer grazing and assigned subjective scores for frame size and muscling. Steers were then fed whole shelled corn ad libitum for 0, 28, 56, 84, 112, and 140 days on feed (DOF), evaluated for performance traits and slaughtered. Carcass data were collected then the left side of each carcass was fabricated and evaluated for various yield, quality, chemical, physical, and palatability characteristics.

Large framed steers had heavier live weights (P<.05) and were taller at the withers (P<.05) than small framed steers throughout the forage feeding phase. All frame size groups were similar in ultrasonic fat thickness measurements during forage feeding.

During grain-finishing, the large framed steers were taller (P<.05) at the withers than the small framed cattle through 140 DOF but past 28 DOF no advantage in frame size, with respect to live weights was discovered. Live fat thickness measurements did not differ (P>.05) among frame size groups. The small framed cattle gained slightly more during grain-finishing than the medium and large framed steers, but no difference (P>.05) was observed among frame size groups for average daily gain or feed efficiency.

Slaughter weight, wither height, fat thickness, and weight gain increased (P<.05) as DOF increased. Differences in average daily gain and feed efficiency were not related with time on feed.
Dressing percent, hot carcass weight, adjusted fat thickness, rib eye area and percentage of kidney, pelvic, and heart fat increased (P<.05) as the length of grain feeding time increased. Yield grade increased (P<.05) with time on feed, remaining within yield grade (1) through 56 DOF, then increased within yield grade (2) through 140 DOF. Marbling degree and quality grade increased (P<.05) as a result of increased grain feeding time. Mean quality grade of low Choice was obtained after 140 DOF. Lean color scores were not affected (P>.05) by DOF, but lean firmness scores increased (P<.05) and external fat generally became whiter as a result of increased DOF.

The proportion of various wholesale cut weights to side weight was affected slightly by live animal frame size except for the proportion of the wholesale round which was higher (P<.05) for the large frame size group than the small. The proportions of wholesale cuts were affected by DOF. Chuck, round, and foreshank proportion of the side weight were found to decrease (P<.05) as DOF increased whereas proportion of the rib, brisket, plate, and flank cuts increased (P<.05) as DOF increased. Proportion of the loin neither increased or decreased, over time, during grain-finishing.

The Biceps femoris muscle weight and area, and femur length were found to increase (P<.05) as DOF increased, but femur weights were similar after 28 DOF. Muscle:bone ratio increased (P<.05) from 0 to 140 DOF but had a low correlation with live animal measurements and muscling score.
Moisture percentage of the *longissimus* muscle decreased (P<.05) and ether extract increased as DOF increased but not linearly with DOF. Nonvolatile cooking loss was affected (P<.01) by DOF and increased with increased grain feeding time, but volatile and total cooking loss were not influenced (P>.05) by DOF. Nonvolatile cooking loss was more closely correlated with carcass fat thickness than marbling degree but both were significant relationships (P<.001).

Taste panel scores for all palatability traits generally increased (P<.05) as DOF increased and steaks from forage-fed steers (0 DOF) were less desirable for flavor, juiciness, and overall acceptability than steaks from grain-fed steers. Tenderness scores through 112 DOF were not significantly different (P>.05) but steaks from steers fed 140 DOF were rated as being more tender (P<.05) than steaks from all other DOF groups. Warner-Bratzler shear values were not affected (P>.05) by length of grain feeding but steaks from 140 DOF group steers had the lowest shear values.

Steaks from carcasses with .2 in. of fat or less had lower (P<.05) scores for flavor and overall acceptability than those with more than .2 in. of external fat. However, carcasses with more than .2 in. of fat had little advantage in tenderness over carcasses having .2 in. of fat or less.

Scores for palatability traits improved as marbling degree increased from practically devoid through small, but steaks with modest marbling had lower flavor and juiciness scores and were...
significantly less tender (P<.05), according to taste panel evaluations than were Good or Standard grade steaks. Flavor and juiciness ratings were lower (P<.05) for steaks from Standard grade carcasses. Marbling was more closely correlated with taste panel flavor scores than tenderness scores.

It was concluded that subjective scores for frame size and muscling have little, if any, benefit in the selection of steers for increased performance. Grain feeding for 140 days, minimum, is required for Hereford steers to reach the low Choice carcass grade. However, feeding steers past 84 days on corn appears to benefit the palatability of beef top loin steaks slightly.
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CHAPTER I

INTRODUCTION

Demand for beef in the United States has been higher than any other red meat since the 1950's. As the per capita income has risen, so has the per capita consumption of beef. Americans prefer high quality beef that is tender, flavorful, and juicy. Health-conscious consumers have demanded recently leaner beef as a way of reducing saturated fats in the diet. This has signaled a demand for good grade carcasses which would be targeted for supermarket retail cases to provide leaner cuts of beef. A modification in feeding practices for slaughter cattle is necessary to meet such a demand and can be accomplished by feeding cattle to a lower finish than comparable Choice grade cattle.

Rapid grain price increases in recent years due to world grain shortages has provided additional incentive for the cattle feeding industry to produce leaner, lower grading beef cattle. Livestock feeders are finding also that competition for grain supplies is greater because of an increasing world demand for these grains as a human food source. World demand for feed grains is expected to increase, creating even greater competition. A rapid increase in the supply of feed grains would result in significant grain price decreases and allow a return to the practice of feeding cattle more grain, namely corn. However, increasing production costs will tend
to hold grain prices at a relatively high price level (Hodgson, 1977). For these reasons and increased investment costs for grain production, cattle production in the United States will become more dependant on available forages.

Beef cattle have the ability to convert otherwise useless forages, not fit for human consumption, into palatable red meat. Large areas of forage resources in the southeastern United States provides such an opportunity for producing slaughter cattle with reduced grain requirements.

Bowling et al. (1978) found that steers grown on grass and then fed concentrates during a limited time on feed produced much more protein than steers grain-fed after weaning, grain-fed on pasture or finished on pasture. Furthermore, it was suggested that the most advantageous feeding regime would include maximum frame and muscle development on forages followed by a short grain finishing period to conserve grain, yet allowing sufficient protein production and assurance of acceptable palatability. Berg and Butterfield (1976) stated that "a low plane of nutrition before the fattening phase begins has little or no effect on ultimate carcass composition provided that the animal is finished on an adequate plane."

The objective of this investigation was to study the effects of forage feeding and time on feed of small, medium, and large frame size Hereford steers on:

1. live animal measurements and performance traits,
2. carcass yield and quality characteristics,
3. ratio of the *Biceps femoris* muscle to femur bone as a measure of development,

4. cooking loss and palatability traits of top loin steaks, and

5. composition of the *Longissimus dorsi*. 
CHAPTER II

REVIEW OF LITERATURE

I. PRODUCTION CHARACTERISTICS

With the advent of increased grain prices, production of slaughter cattle tends to put more emphasis on feeding cattle less grain and higher amounts of forages. When grain prices are low, it becomes economical to finish cattle with more grain. Hodgson (1977) stated that the future of grain feeding beef cattle will depend upon the economical returns from producing beef on high grain rations in comparison with those from producing beef from forages.

In a review comparing forage and grain finished beef, Bidner (1975) remarked that the major concern in comparing these two types of feeding systems has been the lower net energy of forages and the slower gains of cattle produced on this type of diet. Cattle finished on forages therefore require a longer feeding period to reach similar slaughter weights and live animal grades than cattle finished with high concentrate diets. Bowling et al. (1978) supported this conclusion by reporting that steers fed grain reached slaughter weight and live grade 100 to 230 days sooner than steers finished on forages. Wanderstock and Miller (1948) reported that yearling steers in treatments receiving no grain had significantly
lower final grades on foot than steers fed full-feed or grain on pasture.

Since forage finished cattle require a longer feeding period to reach similar slaughter weights of grain-fed cattle, average daily gain is also reduced (Matthews and Bennett, 1962; Anthony et al., 1971; Young and Kauffman, 1978). Utley, Hellwig, and McCormick (1975) found that steers fed a high-energy diet gained 2.97 lbs. daily while steers fed an all-forage diet gained 2.33 lbs. daily. Oltjen, Rumsey, and Putnam (1971) obtained similar results when cattle were finished on one of four feeding treatments: (1) pelleted alfalfa diet, (2) grain-fed diet followed by an all-forage diet, (3) all-forage diet followed by grain feeding, or (4) grain feeding only. Average daily gains and feed/gain ratios for the feeding trials were 2.32 lbs., 10.06; 2.40 lbs., 7.98; 2.45 lbs., 8.14; and 2.80 lbs., 5.71, respectively. As the level of grain feeding was increased, animals gained more rapidly with more efficient feed conversion.

Moody et al. (1970) found that Angus steers had similar daily gains when fed ground shelled corn at a rate of 1.5% of body weight plus corn silage *ad libitum* for 28, 56, 84, or 112 days on feed. Zinn, Durham, and Hedrick (1970a) reported that average daily gain increased as length of time on a high-concentrate diet increased up to 180 days on feed. Perry et al. (1971) studied the effects of grain supplement levels on pasture relative to daily gains of cattle finished on grain. Cattle fed more grain on pasture had
lower average daily gains during the grain finishing phase than cattle fed less concentrate on pasture. Furthermore, each additional pound of body weight the higher supplemented cattle gained on pasture resulted in 0.20 lb. less gain than non-supplemented cattle during the grain finishing phase. Young, Branaman, and Deans (1962) reported that with corn silage being full-fed, delaying the feeding of ground shelled corn for 98 days, followed by full-feeding grain to steers for 184 days, did not appear to alter total gain or feed efficiency as compared with continuous limited grain fed to steers for 275 days at a rate of 1.25 lbs. of corn per 100 lbs. of body weight per day.

Other studies evaluating feed efficiency of beef cattle have discovered contrasting results due to the level of nutrition or type feed used in treatments. Smith et al. (1977) used varying levels of forages ranging from 20% to 96.6% to finish steers and found feed efficiency measured on a pen basis did not differ among feeding treatments or frame size (small vs. large). Klosterman (1972) came to the same conclusion concerning frame size in a review of the subject, stating that when fed to the same level of finish, little if any difference in feed efficiency has been shown among cattle of various sizes, exclusive of carcass weight, grade and composition.

During the feedlot finishing phase, Henrickson, Pope, and Hendrickson (1965) found feed efficiency favored a high level of nutrition (2 lbs. grain per 100 lbs. body weight) versus a moderate
level of nutrition (1 lb. grain per cwt.) by allowing a more rapid rate of gain. Similarly, Guenther et al. (1965) revealed that feed efficiency was greatest during the initial phase of the feedlot period and favored a high level of nutrition over a moderate level on an age constant basis. However, on a weight constant basis, little difference was recorded in feed efficiency between the two levels of nutrition.

II. GROWTH AND DEVELOPMENT OF MUSCLE, BONE, AND FAT

Growth of muscle, bone, and fat in beef cattle is most easily measured by carcass dissection, but certain live animal measurements have been utilized in conjunction with this technique to explain differences in growth of various animals. Slaughter weight, sex, shape, nutrition, and breed can all affect carcass composition (Berg and Butterfield, 1976). Using anatomical dissection of serially slaughtered cattle of different breeds and feeding treatments, Berg and Butterfield (1968) found that individual muscles follow differential growth patterns leading to varying muscle distribution depending on the stage of development. Hiner and Bond (1971) serially slaughtered Angus steer calves between 6 and 36 months of age and reported that rate of muscle growth varied among age groups regardless of feeding regimen but the Biceps femoris muscle increased in proportion of total lean as animals matured while the longissimus dorsi decreased in proportion of total lean. Orme et al. (1960) calculated the standard partial regression coefficients
between the weight of total carcass lean and weight of certain muscles or muscle groups from carcasses of mature Hereford cows and reported coefficients of 0.97 for Biceps femoris 0.82 for sirloin tip muscle group, 0.79 for Longissimus dorsi, and 0.72 for the inside round group, with slaughter weight held constant.

Guenther et al. (1965) revealed that under feedlot conditions, calves slaughtered at average age of 10.8 months had accumulated 86% and 78% of their ultimate carcass lean on a high and moderate level of nutrition, respectively, indicating lean deposition reached its peak at an early age. Also, fat deposition was most rapid during the latter part of the feeding period from weaning to slaughter weight, showing a sharp increase after lean production began to subside. These results correspond with the conclusions of Berg and Butterfield (1968) that bone is considered early developing, muscle is intermediate, and fat is late developing.

Sex

Foster and Miller (1933) revealed differences in growth of cattle due to sex in which heifer carcasses had a higher percentage of fat and a lower percentage of lean and bone than steer carcasses when both groups were fed the same ration for the same amount of time. Also, the steers yielded a higher percentage of the chuck and round wholesale cuts than the heifers. Berg and Butterfield (1976) supported these conclusions and stated that growth patterns in relation to sex have shown that heifers mature at lighter weight
than steers and bulls, thus reaching the fattening state of development at an earlier age.

**Breed**

Callow (1961) found that the percentage of muscular tissue in beef carcasses was influenced by breed as Friesians yielded 60.0% muscular tissue, Herefords yielded 57.1%, and Shorthorns yielded 55.1%. Lipsey, Dikeman, and Schalles (1978) reported that when fed the same ration, Gelbvieh and Maine-Anjou crosses provided carcasses with less external fat, lower yield grade, lower fat percentages of the round and higher percentages of lean and bone in the round than Hereford x Angus reciprocal crossbred steers. Skelley et al. (1980), comparing various crossbreeds, noted that Polled Hereford x Angus steers had more external fat, smaller rib eye areas and higher yield grades than Charolais x Angus or Simmental x Angus steer carcasses. Koch et al. (1976) bred Hereford and Angus cows to Hereford, Angus, Jersey, South Devon, Limousin, Charolais, and Simmental sires and found that growth rate expressed in terms of retail product, fat trim, and bone differed significantly among breed of sire.

Ramsey, Cole, and Hobbs (1962) used 133 steers from varying breeds to study the relation of various yield grade factors to separable lean, fat, and bone. Results indicated less variation in relating yield grades to percent lean and fat within breeds than in pooled samples, suggesting differences among breeds. Similarly,
Abraham et al. (1968) suggested that a given prediction equation to evaluate beef carcass cutability may not be applicable to all breeds due to definite differences among breeds for various carcass measurements.

**Frame Size**

Subjective scores assigned for frame size as well as for muscling to feeder calves prior to finishing have been used as an attempt to explain differences in carcass composition. Tatum et al. (1982b) assigned frame size scores of small, medium, and large and muscle thickness scores (No. 1, No. 2, No. 3) to feeder steers prior to finishing for 112 days on feed. Results revealed a significant difference in the longissimus muscle area between No. 1 and No. 3 muscle thickness groups. Smaller framed cattle possessed more subcutaneous fat than the large or medium framed cattle at the beginning of the finishing period and had the highest percent of intramuscular fat after finishing. Therefore, the smaller framed cattle were more early maturing and the large framed cattle would require more time on feed to reach similar fat composition as the small framed group. Butts et al. (1980) found that frame size score was positively related to carcass weight and days on feed for feeder cattle but muscle score was unrelated to either variable. Furthermore, the effects of frame size were found to be similar to measurements of wither height and body depth and subjective fat was less related to response variables than ultrasonic fat measurements.
Muscle:Bone Ratio

Muscle to bone ratios have been researched extensively in attempts to understand the growth rate of lean tissue with conflicting results reported. Hankins, Knapp, and Phillips (1943) found that beef Shorthorn and dual-purpose Shorthorn steers did not differ between muscle:bone ratio and percent separable fat in the carcass. Also, no relationship existed between muscle:bone ratio and live animal measurements, suggesting that selection of cattle on the basis of conformation is of little value. Callow (1961) found no difference in weight of muscle to bone ratio due to plane of nutrition or differences among breeds.

In contrast, Tallis, Klosterman, and Cahill (1959) discovered a correlation of edible portion to bone ratio with live animal weight to height at the withers ratio and live weight to body length ratio. On this basis, it appears that live animal measurements may have some merit in selection of beef cattle with a greater proportion of lean to bone. Tatum et al. (1982b) reported that feeder cattle with highest muscling scores had the highest muscle:bone ratio (4.1) of the round after finishing while those with the lowest muscle thickness had the lowest ratio (3.4) of the round. Concurring with these results, Moody et al. (1970) found a positive relation of weight, circumference, and length of the femur bone with weight of edible portion from carcasses of serially slaughtered Angus steers.
Berg and Butterfield (1966) revealed that muscle:bone ratios differed among breed groups and was shown to increase with increasing carcass weight. After the effects of carcass weight were removed, the influence of fat percentage upon ratios was negligible. The authors also reported that the rate of rise of muscle:bone ratio was lower as the animal matured. Dolezal et al. (1982a) reported that diet, breed, and sex explained 35.8% of the variation in muscle:bone ratios from the 9th-10th-11th rib section with both age and carcass weight held constant. They concluded that the ratios differed greatly among beef carcasses of similar genetic and management history. Weseli, Good, and Holland (1958) compared Shorthorn, Angus, and Hereford steers and found a correlation existed between bone score of live animals and carcass fat thickness. The authors indicated that steers having larger bone scores tended to have less external fat.

III. EFFECT OF FEEDING TREATMENT ON CARCASS YIELD GRADE FACTORS AND CARCASS COMPOSITION

Numerous investigators have shown the effects of plane of nutrition on carcass composition, influencing the yield of retail product. Fat is the most variable tissue in the carcass and research has shown that finishing cattle on a high density diet results in a higher proportion of fat deposition in the carcass versus a low level (Callow, 1961; Henrickson et al., 1965; Oltjen et al., 1971; Utley et al., 1975; Bowling et al., 1977; Young and Kauffman, 1978;
Aberle et al., 1981). Finishing cattle on a high plane of nutrition also results in carcasses with a higher dressing percentage (Wanderstock and Miller, 1948; Oltjen et al., 1971; Young and Kauffman, 1978; Bowling et al., 1978; Aberle et al., 1981; Solomon et al., 1981) and heavier slaughter weights (Callow, 1961; Harrison et al., 1978; Solomon et al., 1981).

Conversely, a low plane of nutrition utilized during the fattening phase through feeding a high level of roughages will result in a lower proportion of fat in the carcass. Bayne, Meyer, and Cole (1969) supported this conclusion in a study where Hereford steers were fed either corn or corn silage ad libitum for the same amount of time. Steers fed corn silage had an average fat thickness of 0.16 in. while steers finished on corn yielded carcasses with a mean fat thickness of 0.42 in. As a result of less subcutaneous fat deposited from feeding low energy diets of silage or forage, the cattle produced carcasses with higher cutability (Bowling et al., 1978; Skelley et al., 1978; Schroeder et al., 1980; Aberle et al., 1981; Solomon et al., 1981) but had the disadvantage of possessing smaller rib eyes than cattle fed a high energy diet (Schroeder et al., 1980; Aberle et al., 1981; Solomon et al., 1981).

Carcass composition is not only influenced by the level of nutrition but the length of time the animal is sustained on a particular ration as well. As time on feed is increased, various researchers have shown increases in the amount of fat deposition (Callow, 1961; Zinn et al., 1962; Shinn et al., 1976; Dinius and
Cross, 1978; Harrison et al., 1978; Tatum et al., 1980), higher yield grades (Dinius and Cross, 1978; Tatum et al., 1980; Dunn, 1982; Reviere, 1982), heavier carcass weights (Schroeder et al., 1980), and an increase in dressing percentage (Shinn et al., 1976; Dinius and Cross, 1978; Schroeder et al., 1980; Dunn, 1982; Reviere, 1982). Zinn et al. (1962) found that as the number of days on feed increased, rib eye area steadily increased up to 180 days for steers and 120 days for heifers. Moody et al. (1970) reported that Angus steers fed a ground shelled corn ration at a rate of 1.5% of body weight plus corn silage ad libitum had longissimus areas that increased progressively as days on feed increased, but no difference was noted after 56 days on feed.

Grain fed cattle were reported by Bowling et al. (1978) to yield a lower percentage of closely trimmed, boneless retail cuts than forage-fed cattle due to greater fat thickness of the grain-fed carcasses, but the advantage in cutability of the forage-fed cattle was reduced because of the lower dressing percentage. Lusby (1977) reported conflicting results comparing forage and grain fed cattle in which forage-fed cattle produced carcasses with less retail yield than grain finished cattle. Grain-fed cattle have also been shown to possess larger rib eyes than forage-fed cattle (Lusby, 1977; Harrison et al., 1978; Schroeder et al., 1980; Dunn, 1982). Although Weseli, Good, and Holland (1958) reported that as fat thickness increased loin eye area was found to decrease, but did not reveal at what point this phenomenon occurred.
Abraham et al. (1980) cited a significant correlation between beef longissimus area and yield of boneless steak and roast meat. However, fat thickness was the most important variable in multiple regression equations predicting percent of boneless retail product. Other investigators have also found fat thickness over the rib eye to be the most important factor in predicting yield of boneless retail product (Tallis et al. 1959; Murphey et al., 1960; Abraham et al., 1980). Paralleling with these results, Ramsey et al. (1962) concluded that yield grades are negatively associated with separable lean and bone while separable fat is positively associated. In addition, when rib eye area was removed from the yield grade calculations, the resulting yield grades were more closely related to separable lean and fat than when rib eye area was included, indicating that fat has a more definite influence than rib eye area on carcass yield.

IV. EFFECTS OF FEEDING TREATMENT AND BREED ON CARCASS QUALITY TRAITS

Merchandizing beef at the retail level is based not only on cutability, for economic reasons, but also upon the consumers preference for acceptable lean color, firmness and texture, ideal fat color, and a desirable amount of marbling to ensure a high degree of palatability. Through the years consumers have discovered Choice grade beef provided the desired combination of acceptable quality traits and was more economical than the higher quality Prime grade
cuts of beef. Production of slaughter cattle therefore emphasizes finishing cattle to reach the Choice grade for which the slaughter industry pays a premium over the lower grading cattle.

Type of ration and length of feeding has been shown, through extensive research, to affect the rate and amount of fat deposition in the live animal which systematically influences marbling degree of the carcass. The rate and level of intramuscular fat deposition in the *longissimus* muscle is a major concern to the cattle producer for the obvious reason of its effect upon the final quality grade of the carcass. Variation of feeding treatment has also been attributed to differences in lean color and firmness and subcutaneous fat color which is of greater interest to the meat retailer.

Comparing pasture-fed and grain-fed cattle, Bull, Snapp, and Rusk (1941) reported that carcasses from the forage-fed group had slight to extremely yellow fat whereas grain finished cattle had a "creamy" white fat color and had higher quality grades. Bidner (1975) in a review of forage versus grain feeding came to the same conclusion but stated that these differences existed only when cattle were fed forages or grain for the same amount of time. Utley *et al.* (1975) and Leander *et al.* (1978) both found that grain feeding increased marbling degree and improved carcass quality grades compared to forage feeding.

Hunt, Kincaid, and Carter (1953) compared carcasses from cattle fed an adjusted grain ration allowing the same amount of gain as cattle fed on bluegrass-white clover pasture. It was noted
that average carcass grades were practically the same and lean color
did not differ, but pasture-fed cattle were found to have a higher
proportion of yellow color in the fat. A similar effect was
reported by Malphrus (1961) in which grain-fed cattle had whiter,
firmer external fat than pasture-fed cattle when both groups were
finished to the same live grade endpoint. Anthony et al. (1971)
found that cattle slaughtered directly off pasture graded 9% Choice
and 91% Good but no objectionable fat color was observed. When
Hereford steers fed a high forage diet or grain were each slaughtered
at a mean ultrasonic fat thickness of 1.0 cm, Young and Kauffman
(1978) found that marbling in the longissimus muscle was similar
for both groups.

Oltjen et al. (1971) reported that grain-fed steers produced
carcasses with higher quality grades than steers fed an alfalfa
based pelleted forage diet, but cattle fed forages or grain both
graded Choice. In a study involving the effects of feeding different
forages, Cross and Dinius (1978a) found that steers fed alfalfa
hay had more marbling and higher quality grades than steers fed
dehydrated alfalfa meal.

In studies involving the level of grain feeding in combination
with forages, Skelley et al. (1978) and Reagan et al. (1981)
reported that cattle fed forages supplemented with grain produced
carcasses with more marbling and higher quality grades than cattle
fed only forages. Wanderstock and Miller (1948) found that yearling
steers finished on forages alone graded low Commercial to low Good,
cattle fed grain on pasture graded high Good to low Choice, cattle fed grain after pasture graded low Good to low Choice, and steers finished on grain graded low to average Choice. Bowling et al. (1978) revealed that Santa Gertrudis steers fed grass or grain on grass graded 21% average Good, 51% low Good, 18% high Standard with the remaining 10% either above or below these grades. Also, steers which gained 500 lbs. or more during grain finishing had deposited enough marbling to reach the Choice grade. Henrickson et al. (1965) and Solomon et al. (1981) both found that as the rate of gain increased due to increased level of grain feeding, marbling scores and quality grades of the respective carcasses increased.

Research by Davis et al. (1981) comparing forage, limited grain, and grain feeding revealed that grain-fed steers had higher scores for color, firmness, texture, and marbling of the longissimus muscle. Reagan et al. (1977) reported similar results whereby grain on grass feeding provided carcasses with more marbling and higher muscle color scores than carcasses from grass-fed cattle. On the other hand, Wanderstock and Miller (1948) noted only slight differences in lean and fat color due to varying levels of grain-fed on pasture.

Craig, Blumer, and Barrick (1959) concluded that differences in lean color were due to varying amounts of fat and moisture in the rib eye rather than differences in the quality of pigments present in the muscle. But, less yellow pigment was found in the external fat as cattle were fed more grain in the ration. A similar
effect was reported by Schupp et al. (1976) for cattle finished on grass and grain on grass produced carcasses with slight to medium yellow fat while those fed only grain had comparably whiter external fat.

Forage feeding followed by additional time on grain has been shown by several investigators to increase marbling score and quality grade of the carcass (Zinn et al., 1962; Harrison et al., 1978; Dunn, 1982; Reviere, 1982). Zinn et al. (1970a) found marbling score and quality grade to increase as days on feed increased with no significant change after 240 days.

Shinn et al. (1976) reported that steers fed for 112 days on corn had an average quality grade of high Good whereas Dunn (1982) found that a mean quality grade of low Choice was obtained after 84 days of feeding whole shelled corn ad libitum. These varying results are most likely attributable to differences in breed since the former study used Hereford steers and the latter Angus steers. Godfrey et al. (1977) using steers of predominantly Angus breeding noted that carcasses from cattle fed 90 days on feed graded an average of high Good and cattle fed for 110 days graded low Choice.

Weseli et al. (1958) found a definite influence of breed on marbling score with Shorthorn and Angus cattle having more marbling than Herefords. Koch et al. (1976) crossed Hereford and Angus cows with seven different sire breeds and reported that marbling degree was significantly affected by breed of sire but differences in color and firmness of lean and maturity were slight.
Moody et al. (1970) revealed that texture and firmness of the rib eye was not affected by varying lengths of time on feed whereas Schroeder et al. (1980) found that added time on grain improved lean firmness and color, but nevertheless, both studies agreed that marbling degree increased as time on feed increased. In addition, Schroeder et al. (1980) noted that forage-fed cattle exhibited a darker rib eye muscle than grain-fed cattle and concluded this was indicative of greater stress susceptibility.

Wheeling, Berry, and Carpenter (1975) found different results in a comparison study of forage and grain feeding. Forage-fed beef was found to have a finer lean texture and lighter muscle color than grain-fed beef. Dinius and Cross (1978) reported no effect of feeding a 78.5% corn diet or an all-forage diet on lean color, but cattle fed the concentrate diet for 9 weeks attained the low Choice grade while those fed for 3 or 6 weeks on grain graded Good.

As time on feed increases, animal age and carcass bone maturity subsequently increases although Harrison et al. (1978) reported that cattle fed up to 98 days on grain increased bone maturity but remained well within A maturity. However, Tatum et al. (1980) found that 6.0% of the cattle fed 160 days on feed graded Commercial or Utility compared to none at 100 days on feed, but the percentage of carcasses grading Choice increased as time on feed increased.
V. EFFECTS OF FEEDING TREATMENT AND CARCASS CHARACTERISTICS ON COOKING LOSS AND PALATABILITY TRAITS OF BEEF

Cooking Loss

Comparing cattle fed on forages or grain for the same length of time, steaks from grass-fed cattle have generally been found to have less total cooking loss owing to differences in fat content of steaks (Wheeling et al., 1975; Dinius and Cross, 1978; Gutowski et al., 1979). In relation to fat content, Moody et al. (1970) found that the percentage of cooking loss was significantly correlated with weight of fat trim from the primal cuts of beef carcasses. McCampbell, Greene, and Lowrey (1972) reported that cattle fed grain had lower evaporative cooking loss but a higher percentage of non-volatile cooking loss than forage-fed cattle, indicating that the roasts from grain-fed cattle were fatter. However, Armbruster et al. (1981) noted that roasts from cattle fed corn or corn silage ad libitum, ranging in marbling from slight to the abundant degree, had no difference in percent total cooking loss. Meyer et al. (1960) also found no difference in cooking loss comparing forage and grain finishing.

Wanderstock and Miller (1948) and Hunt et al. (1953) fed cattle to the same live grade on forage or grain rations and showed that differences in cooking loss occurred due to feeding regimen with grain-fed cattle having greater cooking loss.

Smith, Carpenter, and King (1969) compared unfrozen steaks with frozen beef steaks and revealed that cooking loss percentages
increased as a result of freezing steaks at -34°C. Jakobsson and Bengtsson (1973) also studied the effects of freezing retail cuts on cooking loss. The authors revealed that a slow rate of freezing resulted in a higher percentage of loss from cooking compared with steaks which were quick frozen.

**Palatability**

Palatability is an essential concern for the consumer and various management practices have been attributed to changes in flavor, tenderness, and juiciness of the *longissimus* muscle (Dube et al., 1971). Extensive research involving the effects of the level of nutrition of rations on the palatability of beef has revealed several contradicting results. Bayne et al. (1969) and Skelley et al. (1978) found that feeding cattle on a high roughage ration without corn reduced sensory panel scores for flavor of beef roasts and steaks compared to cattle finished on corn rations.

Brown et al. (1979) compared ground beef from steers finished on either grass, limited grain ration, or full-fed grain ration and found that a selected panel scored the flavor of ground beef from the limited grain or full-fed grain cattle higher than the grass finished cattle. In other studies comparing varying amounts of grain fed to cattle, Gutowski et al. (1979) and Aberle et al. (1981) both reported that panel flavor and tenderness scores of the *longissimus* muscle increased and shear values decreased as the level of grain feeding was increased. Aberle et al. (1981) also
found that collagen solubility of the rib eye muscle was lower for cattle fed forages than for cattle fed grain.

Miller et al. (1983) varied the length of time cattle were backgrounded on pasture prior to grain finishing for 185 days to obtain youthful (A and B maturity) and mature (C and D maturity) carcasses. Shear force values, palatability traits and collagen solubility were not affected by maturity differences, indicating that the restricted dietary energy of pasture feeding delayed maturation and stabilization of collagen. Harrison et al. (1978) found that cattle fed a high forage diet for 98 days, short-term on grass followed by 49 days on grain and long-term on grass followed by 98 days on grain did not differ in shear values of the Longissimus dorsi, but the latter group scored higher for panel ratings of flavor, tenderness, and juiciness. Schupp et al. (1976) obtained similar results when cattle were slaughtered at an equivalent live weight after finishing on grass, grain on grass, or varying days on feed.

Cover, Cartwright, and Butler (1957), Burson et al. (1980), and Reagan et al. (1981) all reported that the level of nutrition did not affect taste panel scores for flavor, tenderness, and juiciness of loin eye steaks. Jacobson and Fenton (1956) noted that differences in scores for aroma and juiciness and shear force values were not consistent with nutritional level of feed, but as the level of nutrition increased flavor preference increased. Matthews and Bennett (1962), Henrickson et al. (1965), and
Solomon et al. (1981) agreed that neither panel tenderness scores nor Warner-Bratzler shear values differed due to varying rates of gain.

Comparisons of forage and grain finished beef have shown generally that forage finished beef had a less desirable flavor and was less tender (Wanderstock and Miller, 1948; McCampbell et al., 1972; Shinn et al., 1976; Bowling et al., 1977; Lusby, 1977; Smith et al., 1979; Schroeder et al., 1980). The less desirable flavor of forage-fed beef has been attributed to a higher intensity of a dairy flavor compared to a more intense beef flavor in grain-fed beef (Amiri et al., 1980; Davis et al., 1981).

Malphrus (1957) found that a significant number of untrained panel members detected a flavor difference between steaks and roasts with either yellow or white fat, since yellow fat is attributable to feeding cattle high forage rations. Although, no flavor preference was noted between the two samples on the basis of color of fat. Chastain, Huffman, and Bertram (1981) reported similar findings comparing forage and grain-fed steaks and roasts evaluated by triangle testing. Panelists were able to detect differences between samples but no preference for flavor, tenderness, or juiciness was indicated. Even though grain-fed rib steaks had more marbling than forage steaks, Wheeling et al. (1975) found all palatability traits and shear force values to be similar.

Feeding cattle to comparable weights and grades on forage or grain rations results in slight differences of palatability
traits of beef (Hunt et al., 1953; Malphrus, 1961; Bidner, 1975). Oltjen et al. (1971), however, found that steers fed a pelleted alfalfa diet were more tender, more flavorful, and had higher desirability than beef from grain finished steers.

Palatability of beef has been shown to increase as the length of grain feeding is increased (Moody et al., 1970; Shinn et al., 1976) with no improvement between 56 and 112 days on feed. Tatum et al. (1980) found that increasing time on feed from 100 to 160 days had a beneficial affect on flavor, but not on tenderness and juiciness. Likewise, Dolezal et al. (1982b) reported that extending the grain finishing period beyond 100 days provided little additional palatability assurance. Reviere (1982) showed that palatability of top loin steaks improved the most during the first 84 days on feed with no additional change thereafter. However, Instron shear values decreased from 28 to 112 days on feed.

Dunn (1982) also reported that palatability scores increased and Warner-Bratzler shear decreased as time on feed increased up to 140 days and, furthermore, stated that cooked beef fat flavor increased while milky-oily flavor decreased. A similar flavor description was given by Melton et al. (1982) for ground beef samples from a time on feed study. Also, changes in fatty acid content of ground beef occurred during the feeding trial. C18:0 and C18:3, positively correlated with milky-oily flavor, decreased with length of grain feeding while C18:1, correlated with the cooked beef fat flavor, increased.
Zinn et al. (1970b) serially slaughtered steers at 30 day intervals for 270 days on feed. Shear force values were lowest at 150 and 180 days, but after 180 days animal age exerted a negative influence on tenderness. Dinius and Cross (1978) found no difference in tenderness and juiciness of steaks from cattle fed 90, 180, and 270 days on grain, but steers fed hay had the highest Instron shear values.

Forage-fed cattle generally yield carcasses with a thinner fat cover than grain-fed cattle when fed for similar amounts of time. Carcasses with a thick fat cover have been found to be more tender than trim carcasses which was accounted for by differences in the degree of cold shortening (Merkel and Pearson, 1975). Lamb carcasses with 0.3 in. of fat or more were found by Smith et al. (1974) to have significantly lower shear force values for loin chops than lambs with 0.1 in. of fat or less. Bowling et al. (1978) studied the relationship of fat thickness of beef carcasses to tenderness of beef loin steaks. Carcasses with fat thickness less than 0.3 in. were progressively less tender by panel ratings and shear values than carcasses with more than 0.3 in. of fat. Carcasses with fat thickness over the rib eye greater than 0.3 in. were generally similar in tenderness. Dolezal et al. (1982c) reported a similar effect of fat thickness on palatability measurements for tenderness. Steaks from carcasses with more than 0.2 in. of fat rated higher for panel tenderness scores and had lower shear values than carcasses with 0.2 in. or less fat.
Locker and Hagyard (1963) studied the effects of chilling temperature on shortening of the psoas, longissimus, and sternoman-dibularis muscles of beef. A maximum shortening of 47.7% occurred by chilling muscles at 0°C, excised one-half hour after slaughter. Above 2°C, a rapid decline in shortening was observed to a minimum value of less than 10% at temperatures between 14 and 19°C. Howard and Judge (1968) concluded that very small differences in sarcomere lengths of muscles were associated with large differences in tenderness.

Evaluations of other carcass traits on beef palatability have found that regardless of the amount of external fat on the carcass, loin steaks with modest or above marbling were more tender and juicy according to panel ratings and had lower shear values than steaks of slight or less marbling degree (Jennings, Berry, and Joseph, 1978). Tatum, Smith, and Carpenter (1982a) noted that marbling had a low but positive relationship to all palatability traits of beef but the relationship of fat thickness was neither linear nor additive.

Others have reported a significant effect of quality grade on tenderness of beef with shear force decreasing as carcass quality grades increased from Commercial to Good to Choice (Kropf and Graf, 1959) and steaks from the moderate degree of marbling were more tender than steaks with a small degree (Covington et al., 1970) even though no differences in sarcomere lengths were found. Webb, Kahlenberg, and Nauman (1964) reported that 12 and 24 month old
steers were similar in tenderness, even though marbling degrees varied but both groups had significantly lower Warner-Bratzler shear values than loin steaks from 60 month old cattle.

Variations in tenderness have also been related to differences in cooking temperature of steak and roast meat from beef with a decrease in tenderness as internal temperature increased linearly (Leander et al., 1978). Draudt (1972) reviewed this subject concluding that once the shrinkage of collagen is complete in the temperature range of 60 to 65°C, shear values remain constant up to 3 hours whereas cooking at 66-70°C internal temperature increased shear values and solubilization of collagen occurs at 70°C. Davey and Gilbert (1974) reported that three to fourfold decrease in tenderness occurs between 40 and 50°C, attributed to loss of myosin solubility, and further doubling followed by cooking between 65 and 75°C, related to collagen shrinkage. Bouton, Harris, and Ratcliff (1981) found a similar effect occurred but also noted that shear force values for mature cattle were significantly higher than younger cattle at temperatures greater than 60°C, which the authors attributed to the older animals having more thermally stable collagen crosslinks.

VI. EFFECT OF FEEDING TREATMENT ON CHEMICAL CHARACTERISTICS OF THE LONGISSIMUS DORSI

As marbling degree in the carcass increased, the percentage of ether extract of the longissimus muscle was found to increase
linearly (Palmer et al., 1958) and moisture percentage decreased as the fat content of the muscle increased (Garrett and Hinman, 1971). Differences in ether extract have also been positively correlated with carcass weight (Kropf and Graf, 1959). Koch et al. (1976) observed a negative association between growth rate and percentage of intramuscular fat in the rib eye which was the result of different breed groups having similar fat percentage at different carcass weights.

Feeding cattle on grain, compared to forage feeding, has been noted by several investigators to produce carcasses with a higher percentage of ether extract and a lower percentage of moisture in the longissimus muscle (Craig et al., 1959; Wheeling et al., 1975; Bowling et al., 1978). Conversely, Johnston, Moody, and Boling (1976) reported that forage-fed cattle had more ether extract and less moisture in the rib eye muscle than grain-fed cattle, due to heavier carcass weights produced by forage feeding to a low Choice slaughter endpoint. Although grain-fed steers had a higher percentage of ether extract in the loin eye than pasture finished steers, Schroeder et al. (1980) found no difference in moisture content due to feeding regimen. When cattle were fed on forage or grain rations to similar live weights, Hunt et al. (1953) showed the percent ether extract in the rib eye to be similar between treatments.

Moody et al. (1970) and Leander et al. (1978) both found that moisture percent declined and ether extract increased as the
amount of time of grain feeding increased. Comparably, Reagan et al. (1977 and 1981) reported decreased moisture percentage of the rib eye muscle as the amount of grain fed to cattle was increased and grass-fed beef had the highest percentage of water.
CHAPTER III

EFFECTS OF FORAGE FEEDING, LENGTH OF GRAIN FINISHING, AND SUBJECTIVE FRAME SIZE AND MUSCLING SCORES ON THE PERFORMANCE TRAITS OF HEREFORD STEERS

I. SUMMARY

Live weight, wither height, and fat thickness (measured ultrasonically) were measured on 81 Hereford steers during backgrounding on fescue-orchard grass-clover pasture and subsequent grain-finishing on whole shelled corn fed ad libitum. Steers were assigned subjective frame size scores (small, medium, large) and muscling scores prior to grain-finishing for 0, 28, 56, 84, 112, and 140 days on feed (DOF). Average daily gain and feed efficiency were calculated.

The large framed steers were heavier (P<.05) and had greater (P<.05) wither heights than small framed steers on pasture and at all 28 day intervals of grain feeding. No difference (P>.05) in live weights occurred among frame size groups after 28 DOF. Frame size groups did not differ (P>.05) in fat thickness measurements (ultrasonic) during either feeding treatment, nor did they differ (P>.05) in average daily gain and feed efficiency during grain feeding.

Slaughter weight increased (P<.05) as DOF increased. Wither height did not increase significantly after 56 DOF. Fat thickness and weight gain on grain was affected (P<.01) by DOF but average daily gain was not influenced (P>.05) by DOF. Steers were more
efficient in converting feed to weight gain at 112 DOF, measured on a group basis (mean feed efficiency = 6.71 lbs. corn/lb. of gain). Muscling score was unrelated (P>.05) to all live animal measurements.

II. INTRODUCTION

With the advent of increased grain prices in addition to increased investment for procurement of feeder cattle, interest in production of slaughter cattle with reduced grain requirements to limit costs has arisen in recent years. The most obvious management practice to reduce grain feeding would be to reduce the time on feed for cattle, yet, quality must not be sacrificed. Utilization of vast forage resources in the southeastern United States to background feeder calves provides a significant advantage for cattle producers to reduce grain requirements. Thus, forage feeding prior to grain finishing would allow essential frame development and lean tissue growth, since beef cattle have the ability to convert otherwise useless forages into red meat.

Selection of feeder cattle on the basis of conformation and size has been used as an attempt to select cattle that grow more efficiently. Butts et al. (1980) found that frame size score had a positive relationship with days on feed and wither height but muscling scores were unrelated to response variables. Tatum et al. (1982b) noted that smaller framed cattle had more subcutaneous fat than either large or medium framed cattle. Klosterman (1972) and Smith et al. (1977) both concluded that feed efficiency was not
affected by frame size. Increased time on feed has been shown to increase average daily gain (Zinn et al., 1970a) and increase slaughter weight (Bowling et al., 1978), whereas forage-fed cattle had a lower average daily gain than cattle fed grain (Anthony et al., 1971; Young and Kauffman, 1978).

The purpose of this phase of the study was to determine the relationship of subjective scores for frame and muscling, forage feeding and subsequent time on grain on the performance traits of feeder calves.

III. MATERIALS AND METHODS

Eighty-one Hereford steer calves, varying in frame size, were purchased through Tennessee graded feeder calf sales in late October of 1980. Steers were placed on pasture consisting of fescue, orchard grass, and clover in November of 1980 for wintering at The University of Tennessee Plateau Experiment Station at Crossville, Tennessee. Calves were fed mixed grass-legume hay when pastures were covered with snow. Mean live weight of the steers at the beginning of forage feeding was 538 lbs. In April, 1981, cattle were removed from the winter pasture, weighed (mean live weight = 522 lbs.), and placed on another pasture (fescue, orchard grass, and clover) for summer grazing. The steers remained on pasture through the summer until August 6, 1981 when pasture conditions were not adequate to support growth of the steers (mean live weight = 818 lbs.). Live animal weight (lbs.), wither height (in.), and ultrasonic fat
thickness measured along the back at the 12th rib (mm) were obtained for all steers (n = 81) at the beginning of forage feeding in November, beginning of summer grazing in April, and at removal from pasture in August.

At the time steers were removed from pasture, subjective scores for frame size and muscling were assigned to each animal by University of Tennessee Animal Science Department personnel. Steers were then assigned to six days on feed (DOF) groups (Table 1), varying in frame size and muscling, at which time the 0 DOF group (n = 15) was removed directly off grass feeding for slaughter. The remaining five groups (n = 66) were housed in a feeding barn at the University of Tennessee Plateau Experiment Station at Crossville, Tennessee for grain finishing after a 14 day feeding adjustment period. At the end of the adjustment period, the steers were weighed (mean live weight = 788 lbs.) then begun on the grain finishing phase, fed whole shelled corn ad libitum plus 1.1 lbs. of a pelleted 36% protein supplement per head per day and high calcium mineral ad libitum for 28, 56, 84, 112, and 140 DOF. Cattle were slaughtered at 28 day intervals on feed at Lay Packing Company in Knoxville, Tennessee according to the slaughter schedule shown in Table 2. Corn consumption was measured daily on a pen basis (six steers/pen) and live weight, wither height, and ultrasonic fat thickness was measured for all remaining animals at 28 day intervals when slaughter groups were removed from grain feeding.
TABLE 1
EXPERIMENTAL DESIGN (n = 81)

<table>
<thead>
<tr>
<th>Frame size classification</th>
<th>Days on feed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Large&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td>Medium&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5</td>
</tr>
<tr>
<td>Small&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9</td>
</tr>
</tbody>
</table>

<sup>a</sup>Frame size score = 4 minus, 4, 4 plus, 5 minus, 5.
<sup>b</sup>Frame size score = 3 minus, 3, 3 plus.
<sup>c</sup>Frame size score = 1 minus, 1, 1 plus, 2 minux, 2, 2 plus.

TABLE 2
SLAUGHTER SCHEDULE ACCORDING TO DAYS ON FEED (DOF)

<table>
<thead>
<tr>
<th>Slaughter group</th>
<th>n</th>
<th>DOF</th>
<th>Slaughter date</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>0</td>
<td>August 7, 1981</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>28</td>
<td>September 22, 1981</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>56</td>
<td>October 22, 1981</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>84</td>
<td>November 17, 1981</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>112</td>
<td>December 15, 1981</td>
</tr>
<tr>
<td>6</td>
<td>13</td>
<td>140</td>
<td>January 12, 1982</td>
</tr>
</tbody>
</table>
All data were analyzed by analysis of variance with frame size, muscling score, and DOF as fixed variables and by Duncan's New Multiple Range test (Snedecor and Cochran, 1967).

IV. RESULTS AND DISCUSSION

Forage Feeding Phase

Wintering on pasture and hay from November to April (Table 3) resulted in a weight loss for all the steers regardless of frame size classification. Mean live weight loss was much greater for the small framed steers (35.1 lbs.) than for the medium (6.6 lbs.) or large framed steers (5.6 lbs.). During summer grazing, live weight increased considerably for all frame size groups and the large framed steers reached heavier weights (P<.05) than the small frame size group. The same difference was found between the large and small framed cattle at both the beginning of the forage phase (live weight on grass) and beginning of summer grazing (live weight, April). Weight gain of steers on grass increased as frame size increased with a significant difference (P<.05) between the large and small framed cattle (Table 4). These results agree with the conclusions of Aberle et al. (1981) who reported that Charolais-sired steers, being larger framed, had heavier live weights at both the beginning and end of low and high energy feeding treatments than smaller framed Angus-Hereford steers.

Height at the withers was greater (P<.05) for the medium and large framed cattle compared to the small framed cattle at the
TABLE 3
MEANS AND STANDARD DEVIATIONS OF LIVE ANIMAL MEASUREMENTS DURING FORAGE FEEDING PHASE OF STEER DEVELOPMENT AS AFFECTED BY FRAME SIZE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frame size classification</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small ((a))</td>
<td>Medium ((b))</td>
</tr>
<tr>
<td>Live weight (lbs.):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On grass ((d))</td>
<td>515.0 ± 62.2 (h)</td>
<td>533.1 ± 55.(ghi)</td>
</tr>
<tr>
<td>April ((e))</td>
<td>479.9 ± 67.0 (oh)</td>
<td>526.5 ± 61.6 (h)</td>
</tr>
<tr>
<td>Off grass ((f))</td>
<td>758.9 ± 84.7 (h)</td>
<td>818.2 ± 67.2 (h)</td>
</tr>
<tr>
<td>Wither height (in.):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On grass ((d))</td>
<td>40.2 ± 1.5 (h)</td>
<td>42.0 ± 1.3 (i)</td>
</tr>
<tr>
<td>April ((e))</td>
<td>42.0 ± 1.2 (h)</td>
<td>43.4 ± 0.8 (i)</td>
</tr>
<tr>
<td>Off grass ((f))</td>
<td>43.4 ± 1.2 (h)</td>
<td>45.5 ± 1.4 (i)</td>
</tr>
<tr>
<td>Fat thickness (in.):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On grass ((d))</td>
<td>0.11 ± 0.04 (h)</td>
<td>0.11 ± 0.04 (h)</td>
</tr>
<tr>
<td>April ((e))</td>
<td>0.05 ± 0.02 (h)</td>
<td>0.05 ± 0.02 (h)</td>
</tr>
<tr>
<td>Off grass ((f))</td>
<td>0.15 ± 0.06 (h)</td>
<td>0.17 ± 0.06 (h)</td>
</tr>
<tr>
<td>Muscling score ((g))</td>
<td>8.3 ± 1.2 (h)</td>
<td>8.1 ± 1.5 (h)</td>
</tr>
</tbody>
</table>

\(a_{n} = 48\).
\(b_{n} = 28\).
\(c_{n} = 5\).

\(d\) Measurements of steers at beginning of forage phase (November, 1980).

\(e\) Measurements of steers at beginning of summer grazing (April, 1981).

\(f\) Measurements of steers at end of forage phase (August, 1981).

\(g\) Muscling score: 1, 2, 3 = thin; 4, 5, 6 = slightly thin; 7, 8, 9 = medium; 10, 11, 12 = moderately thick; 13, 14 = thick.

\(h, i, j\) Means in a row followed by the same letter are not significantly different (\(P > .05\)).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain on grass (lbs.)</td>
<td>243.9 ± 56.6e</td>
<td>285.1 ± 50.7ef</td>
<td>311.8 ± 79.0f</td>
<td>262.3</td>
</tr>
<tr>
<td>Gain on grain (lbs.)</td>
<td>187.8 ± 128.1e</td>
<td>179.5 ± 107.7e</td>
<td>161.8 ± 88.4e</td>
<td>183.3</td>
</tr>
<tr>
<td>Overall gain (lbs.)d</td>
<td>381.6 ± 145.7e</td>
<td>409.2 ± 120.5e</td>
<td>413.6 ± 122.9e</td>
<td>393.1</td>
</tr>
<tr>
<td>Average daily gain on grain (lbs.)</td>
<td>2.06 ± 1.81e</td>
<td>2.36 ± 0.89e</td>
<td>2.38 ± 1.04e</td>
<td>2.19</td>
</tr>
<tr>
<td>Feed efficiency on grain (lbs. corn/lb. gain)</td>
<td>7.60</td>
<td>8.30</td>
<td>8.74</td>
<td>8.47</td>
</tr>
</tbody>
</table>

\[a_n = 48.\]
\[b_n = 28.\]
\[c_n = 5.\]
\[d\text{Overall gain = gain from beginning of grass phase to slaughter off grass.}\]
\[e,f\text{Means in a row followed by the same letter are not significantly different (P > .05).}\]
beginning of the forage phase. At both the beginning and end of summer grazing, wither height was different (P<.05) among all frame size groups with the large frame size cattle being taller. Also, mean wither height increased with time on grass for all groups (Table 3). Frame size score was positively correlated (P<.001) with wither height at the end of the forage phase r = 0.77. Butts et al. (1980) reported similar results in that the effects of frame size were related to measured wither height.

Ultrasonic fat thickness measurements were similar (P>.05) among all three frame size classifications at various periods of forage feeding, but the large framed steers tended to have less subcutaneous fat than the medium and small framed steers. Overall mean ultrasonic fat thickness measurements decreased during wintering on grass from 0.11 to 0.05 in., but increased to 0.16 in. at the end of summer grazing (Table 3). Ultrasonic fat thickness measurements did not differ (P>.05) with respect to muscling scores.

Live weights obtained during all periods of the forage phase did not differ (P>.05) among muscling groups. Also, mean muscling scores were similar among the small, medium, and large frame size groups (Table 3). Butts et al. (1980) noted a similar effect that muscle scores were unrelated to the performance of feeder calves.

Grain-Finishing Phase

Live weights (Table 5) obtained during grain feeding were higher (P<.05) for the large framed cattle than the small framed
### TABLE 5
MEANS AND STANDARD DEVIATIONS OF LIVE ANIMAL MEASUREMENTS DURING GRAIN FINISHING
PHASE OF SLAUGHTER STEER DEVELOPMENT AS AFFECTED BY FRAME SIZE

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Steers</th>
<th>Frame size classification</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Small</td>
<td>Medium</td>
</tr>
<tr>
<td>Live weight (lbs.):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 DOF&lt;sup&gt;a&lt;/sup&gt;</td>
<td>66</td>
<td>740.6 ± 70.49</td>
<td>797.0 ± 56.49</td>
</tr>
<tr>
<td>28 DOF&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66</td>
<td>822.3 ± 86.79</td>
<td>876.7 ± 83.79</td>
</tr>
<tr>
<td>56 DOF&lt;sup&gt;c&lt;/sup&gt;</td>
<td>51</td>
<td>853.1 ± 109.39</td>
<td>908.8 ± 82.39</td>
</tr>
<tr>
<td>84 DOF&lt;sup&gt;d&lt;/sup&gt;</td>
<td>38</td>
<td>935.7 ± 101.89</td>
<td>978.1 ± 85.09</td>
</tr>
<tr>
<td>112 DOF&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24</td>
<td>1040.3 ± 103.59</td>
<td>1055.0 ± 41.6</td>
</tr>
<tr>
<td>140 DOF&lt;sup&gt;f&lt;/sup&gt;</td>
<td>13</td>
<td>1071.9 ± 88.89</td>
<td>1090.0 ± 67.5</td>
</tr>
<tr>
<td>Wither height (in.):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 DOF&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66</td>
<td>44.0 ± 1.49</td>
<td>45.7 ± 1.2</td>
</tr>
<tr>
<td>56 DOF&lt;sup&gt;c&lt;/sup&gt;</td>
<td>51</td>
<td>44.5 ± 1.49</td>
<td>46.1 ± 1.2</td>
</tr>
<tr>
<td>84 DOF&lt;sup&gt;d&lt;/sup&gt;</td>
<td>38</td>
<td>45.1 ± 1.69</td>
<td>47.1 ± 1.2</td>
</tr>
<tr>
<td>112 DOF&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24</td>
<td>45.6 ± 1.59</td>
<td>47.4 ± 0.69</td>
</tr>
<tr>
<td>140 DOF&lt;sup&gt;f&lt;/sup&gt;</td>
<td>13</td>
<td>45.7 ± 1.39</td>
<td>47.8 ± 0.69</td>
</tr>
<tr>
<td>Fat thickness (in.):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 DOF&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66</td>
<td>0.15 ± 0.069</td>
<td>0.17 ± 0.079</td>
</tr>
<tr>
<td>56 DOF&lt;sup&gt;c&lt;/sup&gt;</td>
<td>51</td>
<td>0.16 ± 0.069</td>
<td>0.19 ± 0.079</td>
</tr>
<tr>
<td>84 DOF&lt;sup&gt;d&lt;/sup&gt;</td>
<td>38</td>
<td>0.27 ± 0.079</td>
<td>0.26 ± 0.069</td>
</tr>
<tr>
<td>112 DOF&lt;sup&gt;e&lt;/sup&gt;</td>
<td>24</td>
<td>0.34 ± 0.129</td>
<td>0.28 ± 0.059</td>
</tr>
<tr>
<td>140 DOF&lt;sup&gt;f&lt;/sup&gt;</td>
<td>13</td>
<td>0.44 ± 0.119</td>
<td>0.44 ± 0.099</td>
</tr>
</tbody>
</table>

<sup>a</sup> DOF = conclusion of 14 day feed adjustment period.

<sup>b</sup> Small (n = 39); medium (n = 23); large (n = 4).

<sup>c</sup> Small (n = 31); medium (n = 17); large (n = 3).

<sup>d</sup> Small (n = 23); medium (n = 13); large (n = 2).

<sup>e</sup> Small (n = 15); medium (n = 8); large (n = 1).

<sup>f</sup> Small (n = 8); medium (n = 4); large (n = 1).

<sup>g,h</sup> Means in a row followed by the same letter are not significantly different (P > .05).
cattle through 28 DOF. After 28 DOF, frame size did not affect 
(P>.05) live animal weight (mean live weight range 56 to 140 DOF = 
884.4 lbs. to 1082.7 lbs.) (Table 5). Weight gain of steers during 
grain feeding and average daily gain did not differ (P>.05) among 
frame size groups (Table 4). Feed efficiency, calculated on a 
group basis, favored the small framed steers but the differences 
were slight. These results concur with the conclusions made 
by Klosterman (1972) and Smith et al. (1977) that slight 
differences in efficiency occurred among cattle of varying 
frame size.

Wither height (Table 5) differed (P<.05) among all three 
frame size groups through 56 DOF with the large framed cattle having 
higher measurements. After 56 DOF, the large framed cattle were 
taller (P<.05) at the withers than the medium and small framed cattle 
but no difference (P>.05) was found between the medium and small 
framed groups. All frame size groups were similar (P>.05) 
in fat thickness for all DOF periods (Table 5).

Differences in live weights and ultrasonic fat thickness 
measurements were unrelated (P>.05) with muscling score which dis- 
agrees with the findings of Tatum et al. (1982b) who reported that 
cattle with thicker muscling scores finished to heavier live weights 
than thinner muscled cattle.

Slaughter weight (Table 6) increased (P<.05) with increased 
DOF from 779.3 lbs. (0 DOF) to 1082.7 lbs. (140 DOF) which was 
similar to the findings of Dunn (1982) and Reviere (1982). Steers
TABLE 6
MEANS AND STANDARD DEVIATIONS OF LIVE ANIMAL MEASUREMENTS AND PERFORMANCE TRAITS DURING GRAIN-FINISHING PHASE OF SLAUGHTER STEER DEVELOPMENT AS AFFECTED BY DAYS ON FEED

<table>
<thead>
<tr>
<th>Variable</th>
<th>Days on feed</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 (n = 15)</td>
<td>28 (n = 15)</td>
</tr>
<tr>
<td>Slaughter weight (lbs.)</td>
<td>779.3 ± 97.5b</td>
<td>843.3 ± 82.8b</td>
</tr>
<tr>
<td>Wither height at slaughter (in.)</td>
<td>44.1 ± 2.0b</td>
<td>44.0 ± 1.9b</td>
</tr>
<tr>
<td>Fat thickness at slaughter (in.)a</td>
<td>0.15 ± 0.06b</td>
<td>0.16 ± 0.05b</td>
</tr>
<tr>
<td>Gain on grain (lbs.)</td>
<td>64.9 ± 46.5b</td>
<td>78.6 ± 64.2b</td>
</tr>
<tr>
<td>Average daily gain (lbs.)</td>
<td>2.32 ± 1.66b</td>
<td>1.40 ± 1.15c</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(lbs. corn/lb. gain)</td>
<td>8.91</td>
<td>11.01</td>
</tr>
</tbody>
</table>

a Ultrasound fat thickness measured at the 12th rib.

Means in a row followed by the same letter are not significantly different (P > 0.05).
fed for 84, 112, and 140 DOF did not differ (P>0.05) in wither height but were taller (P<0.05) than steers fed for 0, 28, or 56 DOF and increased from 44.1 in. (0 DOF) to 46.7 in. (140 DOF). Similar results were reported by Dunn (1982). Weight gain on grain was affected (P<0.01) by DOF and was positively related with no significant increase (P>0.05) after 112 DOF (mean gain on grain = 277.8 lbs.). Differences in average daily gain were not consistent with DOF with the 56 DOF group having a lower gain (P<0.05) than all other groups. This decrease at 56 DOF can be attributed to a respiratory illness which resulted in a low performance of all steers at this period of grain feeding. Increase in weight gain on grain between the 28 and 56 DOF groups (13.7 lbs.) reflects the poor performance of steers between these periods. However, between 56 and 84 DOF, weight gain on grain improved substantially (125.0 lb. increase) indicating steers recovered from this illness. Feed efficiency values, calculated on a group basis, also reflected the poor performance of the 56 DOF group (11.01 lbs. corn/lb. gain). After 56 DOF, feed efficiency improved but differences were slight. Steers fed for 112 DOF had a small advantage in feed efficiency (6.71 lbs. corn/lb. gain) over the 84 and 140 DOF groups. Guenther et al. (1965) reported that feed efficiency was greatest during the initial phase of grain-finishing.
V. CONCLUSION

Large framed cattle had heavier live weights than the small framed cattle at all periods of forage feeding and during the first 28 DOF, but all groups had similar weights thereafter through 140 DOF, suggesting that the larger cattle had an advantage during the pasture phase but the advantage diminished during the grain-finishing phase. This conclusion is also supported by the fact that the large framed cattle gained more on grass than the other frame size groups but all groups had similar gains on grain. However, the smaller framed cattle tended to gain slightly more than the larger steers. The smaller cattle also had slightly more subcutaneous fat (ultrasonic fat thickness) but the differences were not significantly different. In addition, both the small and medium frame size groups had slightly heavier mean live weights than the large group at 112 and 140 DOF. These results imply that the small framed steers matured earlier and reached the point of rapid fat deposition earlier than the large framed steers. The larger framed cattle were significantly taller at the withers than the small framed steers at all measurement periods during both forage feeding and grain-finishing. Frame size score was positively correlated with wither height. Slight differences in average daily gain and feed efficiency were found among frame size groups, suggesting that selection of feeder calves on the basis of size for efficiency is of little, if any value to the cattle feeder.
Slaughter weight increased as DOF increased with the heaviest mean live weight obtained at 140 DOF. Wither height and ultrasonic fat thickness both increased with increased DOF, but wither height did not change significantly after 84 DOF (46.2 in.). Fat thickness increased from 0.15 in. (0 DOF) to 0.44 in. (140 DOF). Gains during grain-finishing increased as DOF increased to 140 DOF (mean gain on grain = 322.9 lbs.). Differences in average daily gain and feed efficiency were not consistent with length of feeding time on a whole shelled corn diet ad libitum and could have been the result of a respiratory illness contracted by the animals during the initial phase of grain-finishing. Feed efficiency was found to be most favorable at 112 DOF (6.71 lbs. corn/lb. gain) and least favorable at 56 DOF (11.01 lbs. corn/lb. gain) due to illness. Muscling scores were unrelated to frame size scores, fat thickness, and live animal weights.
CHAPTER IV

EFFECTS OF TIME ON GRAIN AND FRAME SIZE CLASSIFICATION OF SERIALLY SLAUGHTERED HEREFORD STEERS ON CARCASS YIELD AND QUALITY TRAITS

I. SUMMARY

Hereford steers (n = 81) were grown on a fescue-orchard grass-clover pasture. The first group of steers was then slaughtered immediately after removal from pasture (0 days on feed) and subsequent groups were slaughtered after being fed whole shelled corn ad libitum for 28, 56, 84, 112, or 140 days on feed (DOF). Steers were assigned subjective frame size scores (small, medium, large) and muscling scores (thick, slightly thin, medium, moderately thick, thick) at the beginning of grain-finishing, prior to slaughter of the 0 DOF group. Carcasses were evaluated for yield and quality traits, fabricated into wholesale cuts and the Biceps femoris and femur were removed from each round for muscle:bone ratio calculations.

Hot carcass weight, adjusted fat thickness, rib eye area, percentage of kidney, pelvic and heart fat, and yield grade increased (P<.05) as a result of increased DOF. Marbling degree, quality grade, and lean firmness scores increased (P<.05) with DOF. Differences in lean color were slight (P>.05) and fat color scores were inconsistent, but the 140 DOF carcasses had a whiter (P<.05) fat cover. Mean quality grade of low Choice was obtained after 140 DOF, while
steers slaughtered directly off pasture (0 DOF) had a mean quality grade of high Standard. Wholesale cut weights increased (P<.05) as DOF increased but proportion of wholesale cut weights to chilled side weight for the round and chuck decreased (P<.05) and proportions of the rib, plate, and flank increased (P<.05) as time on grain increased. Proportion of various wholesale cuts did not differ (P>.05) due to differences in frame size classification and muscle:bone ratio was not correlated (P>.05) with frame size score. Femur weights were similar (P>.05) after 28 DOF but femur length increased (P<.05) from 0 to 140 DOF. Muscle:bone ratio increased (P<.05) from 0 to 140 DOF but had a low relationship with live animal measurement and muscling score.

II. INTRODUCTION

Numerous investigators have reported effects of time on feed on various carcass traits. As time on feed increased, amount of fat deposition increased (Zinn et al., 1962; Shinn et al., 1976; Tatum et al., 1980), yield grade increased (Dinius and Cross, 1978; Tatum et al., 1980; Dunn, 1982; Reviere, 1982), carcass weight increased (Schroeder et al., 1980), dressing percent increased (Shinn et al., 1976; Dinius and Cross, 1978), and rib eye area increased (Zinn et al., 1962).

Reviere (1982) reported that muscle to bone ratio of biceps femoris weight to femur weight increased up to 56 days on feed and remained constant with further feeding. Muscle:bone ratios have
also been found to favor cattle with higher muscling scores (Tatum et al., 1982b).

Increased time on feed has also been related to higher marbling degree (Zinn et al., 1962; Harrison et al., 1978). Shinn et al. (1976) reported that Hereford steers fed 112 days on corn had a mean quality grade of high Good.

Moody et al. (1970) found lean firmness of the rib eye was not affected by length of grain feeding. Although, Schroeder et al. (1980) noted an improvement in lean firmness and lean color due to time on feed. Schupp et al. (1976) reported fat color became whiter due to grain feeding whereas Wanderstock and Miller (1948) found only slight differences in fat color by varying the level of grain feeding.

In relation to frame size, Tatum et al. (1982b) found the smaller framed cattle possessed more external fat at the early stage of grain finishing and had more marbling than larger framed cattle.

This study was performed to determine the effect of forage feeding, length of time on grain, and frame size on beef carcass yield and quality.

III. MATERIALS AND METHODS

Materials and methods for Chapter IV are identical to those explained in Chapter III plus the following additions. Each group of steers (0, 28, 56, 84, 112, and 140 DOF) was slaughtered at Lay Packing Company, Knoxville, Tennessee. The carcasses were chilled
at 28°F for 48 hrs. Carcasses were then ribbed between the 12th and 13th ribs and evaluated by USDA Meat Grading Service personnel for lean, skeletal, and overall maturity; marbling degree; USDA quality grade; adjusted fat thickness; rib eye area; estimated percentage of kidney, pelvic and heart fat; and USDA yield grade. Further evaluation of subjective scores for lean color and firmness and fat color were made by personnel of The University of Tennessee Food Technology and Science Department. The left side of each carcass was then transported to The University of Tennessee, Knoxville Meat Laboratory for fabrication and further analyses.

Chilled sides were separated into the forequarter and hindquarter halves and then each quarter was separated into wholesale cuts, according to the procedure described by Wellington (1953), from which untrimmed weights (lbs.) were obtained in addition to kidney, pelvic and heart fat weight (lbs.). The intact Biceps femoris muscle was removed from the round, trimmed of all seam and external fat, and weighed. A cross section of the Biceps femoris was then obtained by making a cut perpendicular to the length of the muscle at a point 45% from the anterior end. Area of the muscle cross section, traced onto acetate paper, was measured with a compensating polar planimeter. The femur was trimmed of all lean, fat and connective tissue, measured for length (in.) and weighed (lbs.) for use in Biceps femoris muscle to femur bone ratio calculations.

All data were analyzed by analysis of variance with frame size and days on feed as fixed variables and by Duncan's New Multiple Range test (Snedecor and Cochran, 1967).
IV. RESULTS AND DISCUSSION

Means and standard deviations of carcass yield and quality traits by days on feed (DOF) are given in Table 7. Dressing percent increased (P<.05) with increased DOF up to 84 days. A slight decrease was observed from 84 to 112 DOF (58.7% to 57.3%, respectively). Dressing percent then increased (P<.05) from 112 DOF to 140 DOF with the highest mean dressing percentage (60.6%) obtained at 140 DOF. This agrees with results reported by Shinn et al. (1976), Dinius and Cross (1978), Schroeder et al (1980), Dunn (1982), and Reviere (1982) that dressing percent increased as time on feed increased.

Increased time on grain produced carcasses with increased (P<.05) weights, greater adjusted fat thickness, larger rib eye areas, and a higher percentage of kidney, pelvic and heart fat. Adjusted fat thickness increased from 0.14 in. (0 DOF) to 0.50 in. (140 DOF). Rib eye area increased from 9.2 in.\(^2\) (0 DOF) to 12.2 in.\(^2\) (140 DOF). All yield grade factors followed the expected trend of feeding a high energy corn diet which resulted in an increase of yield grade over time. However, mean yield grade did not increase (P>.05) after 84 DOF and remained within USDA yield grade 2.

Marbling scores were higher (P<.05) at 140 DOF than all other DOF groups. Mean scores ranged from practically devoid 80 (0 DOF) to small 60 (140 DOF). All carcasses were well within A maturity. Steers fed for 112 DOF had a mean carcass quality grade of high Good which agrees with results reported by Shinn et al. (1976).
### TABLE 7

MEANS AND STANDARD DEVIATIONS OF YIELD AND QUALITY TRAITS OF FORAGE-FED AND GRAIN-FINISHED STEER CARCASSES AS AFFECTED BY DAYS ON FEED

<table>
<thead>
<tr>
<th>Variable</th>
<th>0 (n = 15)</th>
<th>28 (n = 15)</th>
<th>56 (n = 13)</th>
<th>84 (n = 14)</th>
<th>112 (n = 11)</th>
<th>140 (n = 13)</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dressing percent a</td>
<td>52.7 ± 2.2h</td>
<td>55.5 ± 1.8i</td>
<td>55.8 ± 2.4j</td>
<td>58.7 ± 2.7k</td>
<td>57.3 ± 2.6jk</td>
<td>60.6 ± 1.4jk</td>
<td>56.6</td>
</tr>
<tr>
<td>Hot carcass weight (lbs.)</td>
<td>411.7 ± 61.9h</td>
<td>468.5 ± 53.1l</td>
<td>461.1 ± 44.3l</td>
<td>583.1 ± 71.3l</td>
<td>585.6 ± 44.9l</td>
<td>656.5 ± 63.8l</td>
<td>522.7</td>
</tr>
<tr>
<td>Adjusted fat thickness (in.)</td>
<td>0.14 ± 0.10h</td>
<td>0.19 ± 0.09h</td>
<td>0.23 ± 0.08h</td>
<td>0.43 ± 0.13i</td>
<td>0.47 ± 0.13i</td>
<td>0.50 ± 0.17i</td>
<td>0.32</td>
</tr>
<tr>
<td>Rib eye area (in²)</td>
<td>9.2 ± 1.0h</td>
<td>10.3 ± 0.8i</td>
<td>9.7 ± 1.2hi</td>
<td>10.6 ± 0.9j</td>
<td>11.0 ± 1.0j</td>
<td>12.2 ± 1.2k</td>
<td>10.5</td>
</tr>
<tr>
<td>KPH (%)</td>
<td>1.1 ± 0.4h</td>
<td>1.4 ± 0.3i</td>
<td>0.9 ± 0.3h</td>
<td>1.8 ± 0.3j</td>
<td>2.1 ± 0.5k</td>
<td>2.0 ± 0.5jk</td>
<td>1.5</td>
</tr>
<tr>
<td>Yield grade</td>
<td>1.6 ± 0.3h</td>
<td>1.8 ± 0.4h</td>
<td>1.9 ± 0.4h</td>
<td>2.7 ± 0.5i</td>
<td>2.9 ± 0.6l</td>
<td>2.7 ± 0.8i</td>
<td>2.2</td>
</tr>
<tr>
<td>Marbling degree c</td>
<td>2.8 ± 0.6h</td>
<td>3.7 ± 0.5i</td>
<td>3.8 ± 0.8i</td>
<td>4.3 ± 0.5j</td>
<td>5.1 ± 0.8k</td>
<td>5.6 ± 0.7l</td>
<td>4.2</td>
</tr>
<tr>
<td>Quality grade d</td>
<td>2.1 ± 0.7h</td>
<td>3.2 ± 1.3i</td>
<td>3.4 ± 1.8l</td>
<td>4.6 ± 1.3j</td>
<td>6.0 ± 1.5k</td>
<td>7.0 ± 0.8k</td>
<td>4.2</td>
</tr>
<tr>
<td>Lean color score e</td>
<td>5.3 ± 1.2h</td>
<td>5.7 ± 0.5hi</td>
<td>6.2 ± 0.8i</td>
<td>5.8 ± 0.7hi</td>
<td>5.5 ± 0.7h</td>
<td>5.9 ± 1.0hi</td>
<td>5.7</td>
</tr>
<tr>
<td>Lean firmness score f</td>
<td>3.4 ± 1.1h</td>
<td>5.2 ± 0.9i</td>
<td>6.0 ± 1.1j</td>
<td>6.6 ± 1.0jk</td>
<td>6.0 ± 0.9j</td>
<td>7.0 ± 0.8k</td>
<td>5.6</td>
</tr>
<tr>
<td>Fat color score g</td>
<td>3.4 ± 0.8hi</td>
<td>3.9 ± 0.8h</td>
<td>4.5 ± 0.6i</td>
<td>2.9 ± 0.5jk</td>
<td>3.8 ± 0.3h</td>
<td>2.6 ± 0.4k</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- aDressing percent = hot carcass weight; live weight measured approximately 24 hours after slaughter x 100.
- bEstimated kidney, pelvic, and heart fat.
- c1 = devoid; 3 = traces; 5 = small.
- d1 = low Standard; 4 = low Good; 7 = low Choice.
- e2 = very dark red; 4 = moderately dark red; 6 = cherry red.
- f3 = moderately soft; 5 = slightly firm; 7 = firm.
- g1 = creamy white; 3 = slightly yellow; 5 = yellow.
- h, i, j, k, l Means in a row followed by the same letter are not significantly different (P>0.05).
A mean quality grade of low Choice was obtained by feeding 140 DOF. Percentages of carcasses grading Choice, Good, or Standard, respectively, for each DOF treatment were as follows: 0 DOF = 0, 6.7, 93.3; 28 DOF = 0, 33.3, 66.7; 56 DOF = 7.7, 38.5, 53.8; 84 DOF = 7.1, 71.4, 21.4; 112 DOF = 45.5, 54.5, 0; 140 DOF = 84.6, 15.4, 0. Increased time on feed improved (P<.05) lean firmness scores but did not affect (P>.05) color of the rib eye. Schroeder et al. (1980) found both lean firmness and color improved as the length of grain feeding increased. The 56 DOF carcasses had slightly darker rib eyes suggesting that this group of cattle was stressed more than the other groups. The decreased performance of this group is indicated by a slight decrease in carcass weight and rib eye area from 28 to 56 DOF. In addition, the 56 DOF group had a more yellow (P<.05) external fat color than all other feeding groups, which again can be attributed to the poor performance of this group. Steers fed 140 DOF produced carcasses with the whitest (P<.05) fat color. The 112 DOF group had significantly more yellow (P<.05) fat than the 84 and 140 DOF groups and this difference is most likely attributed to a difference in personnel evaluating the 112 DOF group. Fat color scores overall were inconsistent and variability of light at the packing plant, where evaluations were performed, may have contributed to the inconsistent relationship of fat color to DOF.

The larger framed cattle produced heavier (P<.05) carcasses (Table 8) than the smaller framed cattle, but frame size did not
### TABLE 8
MEANS AND STANDARD DEVIATIONS OF CARCASS SIDE WEIGHTS AND UNTRIMMED WEIGHTS OF MAJOR WHOLESALE CUTS BY FRAME SIZE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frame size classification</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small(^a)</td>
<td>Medium(^b)</td>
</tr>
<tr>
<td>Chilled side weight (lbs.)</td>
<td>248.7 ± 54.4(^d)</td>
<td>261.0 ± 47.7(^{de})</td>
</tr>
<tr>
<td>Forequarter weight (lbs.)</td>
<td>129.6 ± 29.1(^d)</td>
<td>136.6 ± 25.2(^d)</td>
</tr>
<tr>
<td>Hindquarter weight (lbs.)</td>
<td>119.1 ± 25.5(^d)</td>
<td>124.3 ± 22.8(^{de})</td>
</tr>
<tr>
<td>Chuck weight (lbs.)</td>
<td>63.6 ± 13.1(^d)</td>
<td>66.2 ± 11.4(^d)</td>
</tr>
<tr>
<td>Rib weight (lbs.)</td>
<td>22.0 ± 6.4(^d)</td>
<td>22.9 ± 5.2(^d)</td>
</tr>
<tr>
<td>Loin weight (lbs.)</td>
<td>39.0 ± 9.2(^d)</td>
<td>41.0 ± 8.3(^d)</td>
</tr>
<tr>
<td>Round weight (lbs.)</td>
<td>59.2 ± 9.9(^d)</td>
<td>62.6 ± 8.9(^{de})</td>
</tr>
</tbody>
</table>

\(^a\)\(^n\) = 48.  
\(^b\)\(^n\) = 28.  
\(^c\)\(^n\) = 5.  
\(^d,e\)Means in a row followed by the same letter are not significantly different (P > 0.05).
have an effect (P>.05) on any other yield grade factors, marbling
degree, lean firmness, or fat color. However, carcasses from the
medium framed steers had higher (P<.05) rib eye color scores than
the large framed steer carcasses. The large framed steer carcasses
possessed slightly less external fat than the medium and small framed
groups. It is postulated that the more "rangy" cattle had greater
susceptibility to stress which would result in a higher post-rigor
muscle pH and a darker colored lean. A higher muscle pH increases
the water holding capacity and Craig et al. (1959) concluded that
differences in lean color were due to variations in fat and moisture
content of the muscle. The large framed cattle also produced
carcasses with slightly lower marbling scores but differences among
frame size groups were not significant (P>.05)

Fat thickness measured ultrasonically on the live steers
prior to slaughter was positively correlated (P<.001) with carcass
adjusted fat thickness with r = 0.87. Both adjusted fat thickness
and marbling score had a positive correlation (P<.001) with lean
firmness, r = 0.70 for both variables, but neither fat measurements
was correlated (P>.05) with lean color scores.

Frame size classification affected (P<.05) hindquarter weight
and round weight (Table 8) with the larger framed steer carcasses
having heavier weights. Weights for the forequarter, chuck, rib,
and loin did not differ (P>.05) among frame size groups. A
correlation coefficient of 0.74 was obtained correlating frame size
score with femur length, whereas Biceps femoris weight to femur
weight ratio had a very low correlation with frame size \((r = -0.18)\), suggesting that the effect of frame size on round weight is due to differences in bone structure and not muscle thickness.

Weights and percentages of untrimmed wholesale cuts affected by DOF are given in Table 9. Weights for all wholesale cuts increased \((P < .05)\) as time on grain increased. However, from 0 to 140 DOF hindquarter, chuck, round, and foreshank percentages of the chilled side weight generally decreased \((P < .05)\) while forequarter, rib, plate, flank, and internal fat percentages increased \((P < .05)\) from slaughter off grass to 140 DOF. The wholesale cuts which decreased in percentage of the side are considered to be the leaner, more muscular portions of the side (chuck, foreshank, and round). The flank, plate, and brisket are fatter cuts and increased fat deposition during grain feeding increased the percentage of these cuts in proportion to the side weight. Percentage of the rib did not increase \((P > .05)\) through 112 DOF but by 140 DOF, the percentage increased \((P < .05)\) probably as a result of combined increased fat deposition, externally and intramuscularly, and increased rib eye area. Percentage of the loin remained constant \((P > .05)\) among all DOF treatments and this similarity can be explained by the differences between the short-loin and the sirloin in proportions of lean to fat. Calculated percentages of kidney, pelvic and heart fat were higher on a single side basis than the estimated percentages on a whole carcass basis across all DOF groups. Wholesale cut percentages did not differ \((P > .05)\) with respect to frame size. Berg
<table>
<thead>
<tr>
<th>Variable</th>
<th>0 (n = 15)</th>
<th>28 (n = 15)</th>
<th>64 (n = 13)</th>
<th>112 (n = 11)</th>
<th>140 (n = 13)</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilled side weight (lbs)</td>
<td>195.6 ± 27.7c</td>
<td>227.9 ± 25.8d</td>
<td>225.3 ± 22.9d</td>
<td>285.0 ± 36.2e</td>
<td>285.5 ± 22.5e</td>
<td>322.7 ± 32.0f</td>
</tr>
<tr>
<td>Forequarter:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hindquarter:</td>
<td>100.9 ± 14.0c</td>
<td>119.3 ± 13.3d</td>
<td>117.0 ± 11.7d</td>
<td>143.7 ± 19.5e</td>
<td>149.8 ± 12.4e</td>
<td>169.7 ± 16.8f</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>91.8±</td>
<td>92.3±</td>
<td>91.7±</td>
<td>92.7±</td>
<td>92.7±</td>
<td>92.7±</td>
</tr>
<tr>
<td>Chuck:</td>
<td>110.6 ± 14.1c</td>
<td>108.6 ± 12.3d</td>
<td>108.2 ± 11.4d</td>
<td>132.5 ± 17.2e</td>
<td>135.7 ± 10.5f</td>
<td>153.1 ± 15.5f</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>94.7±</td>
<td>97.8±</td>
<td>94.3±</td>
<td>96.7±</td>
<td>94.7±</td>
<td>94.7±</td>
</tr>
<tr>
<td>Rib:</td>
<td>52.9 ± 7.1c</td>
<td>57.4 ± 6.1c</td>
<td>56.7 ± 5.9c</td>
<td>48.7±</td>
<td>48.7±</td>
<td>48.7±</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>27.7±</td>
<td>25.7±</td>
<td>25.7±</td>
<td>25.7±</td>
<td>25.7±</td>
<td>25.7±</td>
</tr>
<tr>
<td>Loin:</td>
<td>16.5 ± 2.3c</td>
<td>18.9 ± 2.4c</td>
<td>19.2 ± 2.5c</td>
<td>25.2 ± 3.9d</td>
<td>25.5 ± 3.4d</td>
<td>30.8 ± 5.9e</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>8.7±</td>
<td>8.7±</td>
<td>8.7±</td>
<td>8.7±</td>
<td>8.7±</td>
<td>8.7±</td>
</tr>
<tr>
<td>Round:</td>
<td>30.6 ± 4.5c</td>
<td>35.1 ± 4.6d</td>
<td>35.5 ± 5.0d</td>
<td>44.2 ± 4.9e</td>
<td>50.8 ± 5.6f</td>
<td>43.9</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>15.7±</td>
<td>15.7±</td>
<td>15.7±</td>
<td>15.7±</td>
<td>15.7±</td>
<td>15.7±</td>
</tr>
<tr>
<td>Foreskank:</td>
<td>51.0 ± 7.4c</td>
<td>55.7 ± 5.6d</td>
<td>56.1 ± 4.6d</td>
<td>63.8 ± 7.9f</td>
<td>68.3 ± 9.9g</td>
<td>71.5 ± 6.4h</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>28.7±</td>
<td>28.7±</td>
<td>28.7±</td>
<td>28.7±</td>
<td>28.7±</td>
<td>28.7±</td>
</tr>
<tr>
<td>Brisket:</td>
<td>8.4 ± 1.3c</td>
<td>10.7 ± 1.2de</td>
<td>10.5 ± 1.0ed</td>
<td>11.8 ± 1.5ef</td>
<td>10.9 ± 1.0ed</td>
<td>11.9 ± 1.6ef</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
</tr>
<tr>
<td>Plate:</td>
<td>9.3 ± 1.4c</td>
<td>13.5 ± 2.7d</td>
<td>13.4 ± 2.6d</td>
<td>16.7 ± 3.5e</td>
<td>15.8 ± 1.7e</td>
<td>18.1 ± 3.0f</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>4.7±</td>
<td>5.9±</td>
<td>5.9±</td>
<td>5.9±</td>
<td>5.9±</td>
<td>5.9±</td>
</tr>
<tr>
<td>Flank:</td>
<td>13.8 ± 2.8c</td>
<td>18.2 ± 2.7d</td>
<td>16.9 ± 2.4d</td>
<td>22.0 ± 3.4e</td>
<td>22.3 ± 2.4e</td>
<td>27.0 ± 3.2f</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>7.7±</td>
<td>7.7±</td>
<td>7.7±</td>
<td>7.7±</td>
<td>7.7±</td>
<td>7.7±</td>
</tr>
<tr>
<td>Kidney, pelvic, and heart fat:</td>
<td>9.4 ± 2.5c</td>
<td>12.4 ± 2.2d</td>
<td>12.0 ± 1.6d</td>
<td>10.2 ± 0.9d</td>
<td>12.9 ± 1.9d</td>
<td>20.9 ± 2.4e</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>4.8±</td>
<td>5.7±</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
<td>4.7±</td>
</tr>
</tbody>
</table>

*Left side of carcass.

Mean percentage of chilled side weight.

C.D.S.F. Means in a row followed by the same letter are not significantly different (P > .05).
and Butterfield (1968) concluded muscle percentage was highest during early development of cattle and the proportion of fat increased while muscle decreased on a high nutritional plane.

_Biceps femoris_ weight increased (P<.05) as DOF increased, with the exception of the 56 DOF treatment (Table 10). _Biceps femoris_ area followed the same trend but the increase was slight after 84 DOF. Femur weight and length measurements were lowest (P<.05) at slaughter off grass with no difference in weight after 28 DOF and no significant difference in length after 84 DOF revealing that bone development ceased during the early stage of grain-finishing. _Biceps femoris_ weight to femur weight ratio (muscle:bone ratio) decreased (P<.05) from 0 to 56 DOF due to the poor performance of steers through this period, but increased (P<.05) from 2.23 (56 DOF) to 2.84 (140 DOF). These results agree with the findings of Berg and Butterfield (1966) in which muscle:bone ratios increased as carcass weight increased. Tatum et al. (1982b) reported a positive relationship between muscling score and muscle:bone ratio. Although, in this study a low correlation was observed between muscling score and muscle:bone ratio, r = 0.27. Low correlations were obtained for live animal measurements with muscle:bone ratios with weight gain during grain finishing providing the highest correlation, r = 0.54. _Biceps femoris_ area was highly correlated with round weight (r = 0.89), as would be expected and rib eye area was positively associated having a correlation coefficient of 0.69.
TABLE 10
MEANS AND STANDARD DEVIATIONS OF BICEPS FEMORIS AND FEMUR MEASUREMENTS AS AFFECTED BY DAYS ON FEED

<table>
<thead>
<tr>
<th>Variable</th>
<th>Days on feed</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 (n = 15)</td>
<td>28 (n = 15)</td>
</tr>
<tr>
<td>Biceps femoris weight (lbs.)</td>
<td>9.1 ± 1.5c</td>
<td>10.1 ± 1.1d</td>
</tr>
<tr>
<td>Biceps femoris area (in²)</td>
<td>13.4 ± 1.5c</td>
<td>15.6 ± 1.8d</td>
</tr>
<tr>
<td>Femur weight (lbs.)</td>
<td>3.6 ± 0.5c</td>
<td>4.0 ± 0.4d</td>
</tr>
<tr>
<td>Femur length (in.)*</td>
<td>14.0 ± 0.7c</td>
<td>14.3 ± 0.3d</td>
</tr>
<tr>
<td>Muscle:bone ratio</td>
<td>2.54 ± 0.24c</td>
<td>2.52 ± 0.15c</td>
</tr>
</tbody>
</table>

*aMissing data at 28 days on feed.

*bBiceps femoris weight divided by femur weight.

c,d,eMeans in a row followed the same letter are not significantly different (P > .05)
On the basis of the results of this study, live animal measurements are of little value in the selection of feeder cattle with higher muscle:bone ratios.

V. CONCLUSION

Dressing percent, hot carcass weight, adjusted fat thickness, rib eye area, estimated percentage of kidney, pelvic and heart fat, and USDA yield grade increased with increased time on grain with the 140 DOF treatment having the highest values. Marbling score and quality grade increased as DOF increased and a mean quality grade of low Choice was obtained by 140 DOF. Lean firmness scores increased as DOF increased but lean color scores differed only slightly. Differences in external fat color were inconsistent, although, feeding for 140 DOF produced carcasses with a whiter fat color.

Frame size had an effect on carcass weight with heavier carcasses obtained from the large framed cattle. All other yield grade factors were not influenced by frame size but lean color scores favored the smaller framed cattle. Differences in marbling, lean firmness, and fat color were slight among the small, medium, and large frame size groups. Fat thickness (measured ultrasonically) at slaughter was correlated with adjusted fat thickness on the carcass and adjusted fat thickness and marbling were correlated with lean firmness but not with lean color scores.
Hindquarter weights and round weights were higher for the large framed steer carcasses but wholesale cut percentages did not differ among frame size classifications. Frame size was positively correlated with femur length but not with muscle:bone ratio of the round. Weights of all untrimmed wholesale cuts increased with respect to DOF, but percentage of the chuck, round, and foreshank decreased while percentages of rib, plate, and flank increased as days on feed increased.

Biceps femoris weight and area measurements were higher by the end of the grain-finishing period (140 DOF). Femur weight and length was lowest at 0 DOF and increased slightly due to length of feeding treatment. Muscle:bone ratio was highest at 140 DOF. Low correlations were obtained for muscle:bone ratio with live animal measurements. Biceps femoris area was positively correlated with weight of the round and rib eye area.
CHAPTER V

EFFECT OF FORAGE FEEDING AND LENGTH OF GRAIN FINISHING ON COMPOSITION, COOKING, AND PALATABILITY TRAITS OF BEEF TOP LOIN STEAKS

I. SUMMARY

Hereford feeder steers (n = 81) were backgrounded on fescue, orchard grass, clover pasture then fed whole shelled corn ad libitum for 0, 28, 56, 84, 112, and 140 days on feed (DOF), then slaughtered. Carcass data were collected then the left side of each carcass was fabricated and the short-loin was removed and aged 10 days, after which top loin steaks were removed for chemical, physical, and sensory evaluation. Moisture percentage of the rib eye muscle decreased (P<.05) and ether extract increased as DOF increased. However, the increases in intramuscular fat were not always consistent with the length of time on grain. Nonvolatile cooking loss increased (P<.05) as DOF increased and carcass fat thickness influenced nonvolatile cooking loss differences to a greater extent than did marbling degree. Taste panel scores for all palatability traits generally increased (P<.05) as DOF increased and steaks from steers slaughtered directly off pasture were found to have less desirable flavor, less juiciness, and scored lower for overall acceptability than steaks from steers fed for 140 DOF. Steaks from steers fed for 140 DOF were more tender (P<.05) than at other DOF and had the
lowest shear force value. Steaks from carcasses with .2 in. of fat or less scored lower (P<.05) for flavor than those with more than .2 in. external fat but were similar in ratings for tenderness. Shear force values were not affected by differences in fat thickness but steaks from carcasses with more than .6 in. external fat had slightly lower shear values than those having less than .6 in. of fat. Palatability ratings increased (P<.05) as marbling degree increased, but steaks with a small degree of marbling had higher (P<.05) ratings for tenderness and overall acceptability than steaks with a modest degree of marbling. Marbling had a low correlation with panel tenderness ratings and was more closely correlated with flavor and juiciness scores. Steaks from the Choice grade carcasses were more tender (P<.05) than steaks from Good and Standard carcasses, according to taste panel ratings but did not differ with Good grade carcasses in ratings for flavor, juiciness, and overall acceptability. Steaks from Choice and Good grade carcasses rated higher (P<.05) than Standard grade carcasses for flavor, juiciness, and overall acceptability.

II. INTRODUCTION

Extensive research has been centered on the effect of various management systems on carcass composition with fat content having the greatest variability. Palmer et al. (1958) noted that as marbling degree increased, percentage of ether extract in the rib eye increased linearly and differences in intramuscular fat have
been positively correlated with carcass weight (Kropf and Graf, 1959). Increased time on feed was found to increase ether extract and decrease moisture content of the longissimus muscle. As a result of increased fat deposition due to grain feeding, McCampbell et al. (1972) reported lower evaporative and higher nonvolatile cooking losses than beef roasts from forage-fed cattle. However, Meyer et al. (1960) found no difference between forage and grain-fed beef for cooking loss.

Beef from forage-fed cattle had a less desirable flavor and was less tender than grain-fed beef (Wanderstock and Miller, 1948; Shinn et al., 1976; Bowling et al., 1977; Smith et al., 1979; Schroeder et al., 1980). Palatability of beef also increased as the period of grain feeding increased (Moody et al., 1970; Shinn et al., 1976; Dunn, 1982) as a result of increased cooked beef fat flavor and decreased milkly-oily flavor (Melton et al., 1982). Tatum et al., (1980) reported increasing time on feed from 100 to 160 days benefited flavor, but not tenderness and juiciness. Extending the grain finishing period beyond 100 days provided only a slight increase in palatability (Dolezal et al., 1982b). Steers serially slaughtered at 30 day intervals had lowest shear values at 150 and 180 days on feed (Zinn et al., 1970b).

The purpose of this phase of the study was to determine the relationship of grain feeding time on chemical composition, cooking loss, and palatability of top loin steaks.
III. MATERIALS AND METHODS

Materials and methods for Chapter V are identical to those outlined in Chapters III and IV with the following additional procedures. After separation of wholesale cuts was completed, the tenderloin was removed from the loin, then the short-loin and sirloin were separated. The short-loin was wrapped in polyurethane film for aging at 38°F for 10 days from the time of slaughter, prior to removal of steaks for further analyses. Four top loin steaks were removed from each short-loin, starting from the eye end. Steak 1 (1.5 in. thick), was stripped of all epimysium tissue, fat and bone around the longissimus muscle, was frozen in liquid nitrogen and powdered in a high speed blender for proximate analysis of fat and moisture. Triplicate powdered samples, approximately 2.0 grams each, were dried in a vacuum oven at 70°C for 5 hours according to AOAC (1975) procedure. After drying, samples were placed in a dessicator to cool to room temperature and were then weighed to measure moisture loss. The same dried samples were then placed in a Soxhlet apparatus and extracted with anhydrous ethyl ether for 24 hours. Samples were then removed and ether allowed to evaporate prior to drying again by the same AOAC (1975) method. Samples were then removed, cooled in a dessicator, and weighed to determine fat content on a wet and dry basis.

Steak 2, (1.0 in. thick) was removed posterior to steak 1 and was used to determine objective tenderness using the Warner-Bratzler shear method as outlined by Bratzler (1949). Volatile,
nonvolatile, and total cooking losses (%) were also determined using steak 2. Steaks were cooked to an internal temperature of 70°C in a Despatch rotary hearth, modified oven broiling unit set at 400°F. Weights for steaks were obtained prior to cooking and subsequently weighed again after cooking to determine cooking losses. Steaks were allowed to cool to room temperature then 10 cores (0.5 in. diameter) were obtained from various points within the longissimus muscle and each core was sheared twice with a Warner-Bratzler shear to determine objective tenderness.

Steak 3 (1.0 in. thick) removed immediately posterior to steak 2, was used for sensory analysis and steak 4, also 1.0 in. thick, was removed for use in taste panel training. Both steaks were cooked to an internal temperature of 70°C by the aforementioned oven broiling method. Samples of the cooked longissimus muscle (approximately 0.5 in. x 0.5 in.) were evaluated by a 14 member panel comprised of University of Tennessee faculty, staff, and graduate students using a nine point hedonic scale for flavor desirability (1 = extremely undesirable, 9 = extremely desirable), tenderness (1 = extremely tough, 9 = extremely tender), juiciness (1 = extremely dry, 9 = extremely juicy), and overall acceptability (1 = extremely undesirable, 9 = extremely desirable).

All steaks were double wrapped in an oxygen barrier freezer wrap and frozen at -22°F for approximately 24 hours, then were stored at 0°F until analyses were performed.
All data were analyzed by analysis of variance with days on feed and frame size as fixed variables and by Duncan's New Multiple Range test (Snedecor and Cochran, 1967).

IV. RESULTS AND DISCUSSION

As the length of grain feeding increased, percentage of moisture (Table 11) in the longissimus muscle decreased (P<.05) and fat percentage, on both wet and dry basis increased (P<.05), although the increases were not linear. Percentage ether extract increased from 0 to 28 DOF, decreased from 28 to 56 DOF, then increased significantly at 84 DOF but was shown to decrease at 112 DOF. The drop in percentage ether extract at 56 DOF was the result of illness, whereas the decrease at 112 DOF can only be postulated to be the effect of stressful conditions of the cold environment at time of slaughter or stress during transportation for slaughter. However, the decrease was slight and steers slaughtered at 140 DOF had the highest percentage of intramuscular fat (19.3%, dry basis; 5.6%, wet basis). Fat percentages were positively correlated with marbling score, r = 0.84. Fat was positively correlated with lean firmness and moisture percent was negatively correlated (P<.001) showing that as fat percentage is increased and water decreased, lean firmness is increased. Ether extract and moisture percentages were not correlated with lean color scores.

Volatile cooking loss (Table 11) was not affected (P>.05) by DOF treatments but nonvolatile loss was influenced (P<.05) by length of grain feeding. Correlation coefficients of marbling and
<table>
<thead>
<tr>
<th>Variable</th>
<th>0 (n = 15)</th>
<th>28 (n = 15)</th>
<th>56 (n = 13)</th>
<th>84 (n = 14)</th>
<th>112 (n = 11)</th>
<th>140 (n = 13)</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>75.2 ± 0.8b</td>
<td>74.0 ± 0.8c</td>
<td>73.7 ± 0.9c</td>
<td>72.4 ± 1.1d</td>
<td>72.6 ± 1.5d</td>
<td>71.2 ± 1.3e</td>
<td>73.26</td>
</tr>
<tr>
<td>Fat (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet basis</td>
<td>2.0 ± 0.5b</td>
<td>2.7 ± 0.4b</td>
<td>2.6 ± 0.6b</td>
<td>4.4 ± 1.0c</td>
<td>3.4 ± 1.6c</td>
<td>5.6 ± 1.4d</td>
<td>3.48</td>
</tr>
<tr>
<td>Dry basis</td>
<td>8.1 ± 1.8b</td>
<td>10.3 ± 1.3b</td>
<td>9.9 ± 2.2b</td>
<td>15.9 ± 3.1c</td>
<td>14.2 ± 5.2c</td>
<td>19.3 ± 4.1d</td>
<td>12.75</td>
</tr>
<tr>
<td>Cooking losses (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile</td>
<td>12.7 ± 1.4b</td>
<td>13.1 ± 1.0b</td>
<td>12.6 ± 2.4b</td>
<td>12.5 ± 1.6b</td>
<td>13.0 ± 1.1b</td>
<td>12.2 ± 1.1b</td>
<td>12.7</td>
</tr>
<tr>
<td>Nonvolatile</td>
<td>4.3 ± 1.0b</td>
<td>4.7 ± 0.8b</td>
<td>5.1 ± 1.0b</td>
<td>6.1 ± 1.0c</td>
<td>6.7 ± 0.7cd</td>
<td>5.9 ± 1.2d</td>
<td>5.4</td>
</tr>
<tr>
<td>Total</td>
<td>17.0 ± 1.7b</td>
<td>17.8 ± 1.5bc</td>
<td>17.7 ± 2.7bc</td>
<td>18.6 ± 2.0cd</td>
<td>19.8 ± 1.6d</td>
<td>18.1 ± 1.6bc</td>
<td>17.0</td>
</tr>
<tr>
<td>Palatability traits:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor a</td>
<td>4.3 ± 0.6b</td>
<td>4.8 ± 0.7c</td>
<td>5.2 ± 0.6d</td>
<td>5.7 ± 0.4e</td>
<td>5.6 ± 0.5de</td>
<td>5.6 ± 0.4de</td>
<td>5.2</td>
</tr>
<tr>
<td>Tenderness a</td>
<td>5.7 ± 0.5bc</td>
<td>5.4 ± 0.5b</td>
<td>5.5 ± 0.8bc</td>
<td>5.9 ± 1.0d</td>
<td>5.8 ± 0.9cd</td>
<td>6.4 ± 0.6e</td>
<td>5.8</td>
</tr>
<tr>
<td>Juiciness a</td>
<td>5.5 ± 0.5b</td>
<td>5.8 ± 0.4c</td>
<td>5.9 ± 0.3c</td>
<td>5.9 ± 0.4c</td>
<td>6.1 ± 0.3cd</td>
<td>6.3 ± 0.5d</td>
<td>5.9</td>
</tr>
<tr>
<td>Overall acceptability a</td>
<td>4.5 ± 0.6b</td>
<td>4.0 ± 0.7c</td>
<td>5.2 ± 0.6cd</td>
<td>5.6 ± 0.4e</td>
<td>5.5 ± 0.6de</td>
<td>5.7 ± 0.5e</td>
<td>5.2</td>
</tr>
<tr>
<td>Warner-Bratzler shear (lbs.)</td>
<td>8.2 ± 2.1bc</td>
<td>8.5 ± 1.1bc</td>
<td>8.8 ± 2.0c</td>
<td>8.7 ± 1.9c</td>
<td>8.9 ± 1.9c</td>
<td>7.1 ± 1.1b</td>
<td>8.36</td>
</tr>
</tbody>
</table>

a1 = extremely undesirable flavor, tough, dry, undesirable; 5 = acceptable; 9 = extremely desirable flavor, tender, juicy, desirable.

b, c, d, e Means in a row followed by the same letter are not significantly different (P> .05)
adjusted fat thickness with nonvolatile cooking loss were 0.57 and 0.75, respectively, revealing that external carcass fat had a greater influence than intramuscular fat. Total cooking loss followed the trend of nonvolatile cooking loss since volatile losses were constant. The forage-fed steaks had slightly less total cooking loss than all grain-fed groups.

Taste panel scores for all palatability traits increased (P<.05) as time on grain increased (Table 11). Flavor scores were similar after 84 DOF, and 0 DOF steaks were rated lowest (P<.05) for flavor and were less than acceptable. Tenderness scores were generally similar through 112 DOF but a significant increase (P<.05) in tenderness, evaluated by a trained taste panel, occurred between 112 DOF (5.8) and 140 DOF (6.4). All groups had mean ratings for tenderness within or above the acceptable range. Juiciness ratings progressively increased as DOF increased. The 0 DOF steaks had the lowest score and 140 DOF steaks had the highest rating for juiciness. Overall acceptability scores also increased in relation to DOF. These results agree with findings reported by Wanderstock and Miller (1948), Shinn et al. (1976), Bowling et al. (1977), Smith et al. (1979), and Schroeder et al. (1980) that forage-fed beef had a less desirable flavor and was less tender than grain-fed beef. Tatum et al. (1980) found that feeding grain past 100 days affected flavor but not tenderness or juiciness. The results of this study show that feeding past 84 DOF did not affect flavor but tenderness and juiciness improved by feeding grain up to 140 days. Warner-Bratzler
shear measurements of tenderness was lowest for steaks from steers slaughtered at 140 DOF but did not differ (P>.05) with shear force measurements of the forage-fed steaks (0 DOF). Warner-Bratzler shear measurements were correlated with panel tenderness scores (r = -0.76) but the correlation with marbling score was low.

Dolezal et al. (1982c) reported that steaks from carcasses with more than 0.2 in. external fat were more tender than steaks from carcasses with less than 0.2 in. fat. To evaluate the effects of carcass fat thickness on palatability traits, carcasses were separated into four groups of fat thickness range, differing in increments of 0.2 in. (Table 12). Steaks from carcasses with less than 0.2 in. of fat had lower (P<.05) scores for flavor and overall acceptability than steaks from carcasses with more than 0.2 in. of external fat. Panel tenderness scores were lowest (tougher) for carcasses with 0.2 in. or less fat but differed (P<.05) only with the 0.61 to 0.80 in. carcass fat thickness range. Juiciness ratings were lower (P<.05) for steaks from carcasses with .20 in. or less fat than carcasses with more than 0.4 in. of fat. Warner-Bratzler shear measurements did not differ (P>.05) among the fat thickness groups but carcasses with more than 0.6 in. were slightly more tender. Differences among marbling degree classification (practically devoid, traces, slight, small, and modest) for panel ratings of palatability traits were inconsistent (Table 12) but steaks with small degree of marbling were more tender (P<.05) than steaks with a modest, slight, traces, or practically devoid degree
**TABLE 12**

MEANS OF PALATABILITY TRAITS OF FORAGE- AND GRAIN-FED BEEF CARCASSES AS AFFECTED BY FAT THICKNESS AND MARBLING DEGREE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted fat thickness ranges (in.)</th>
<th>Marbling degree</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.01-.20 (n = 30)</td>
<td>.21-.40 (n = 32)</td>
<td>.41-.60 (n = 13)</td>
</tr>
<tr>
<td>Taste panel evaluations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;c&lt;/sup&gt; 5.4&lt;sup&gt;d&lt;/sup&gt; 5.9&lt;sup&gt;d&lt;/sup&gt; 5.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.5&lt;sup&gt;x&lt;/sup&gt; 5.0&lt;sup&gt;xy&lt;/sup&gt; 5.4&lt;sup&gt;yz&lt;/sup&gt; 5.7&lt;sup&gt;z&lt;/sup&gt; 5.2&lt;sup&gt;yz&lt;/sup&gt;</td>
<td>5.2</td>
</tr>
<tr>
<td>Tenderness&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.4&lt;sup&gt;c&lt;/sup&gt; 6.0&lt;sup&gt;cd&lt;/sup&gt; 5.9&lt;sup&gt;cd&lt;/sup&gt; 6.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.6&lt;sup&gt;x&lt;/sup&gt; 5.4&lt;sup&gt;x&lt;/sup&gt; 5.8&lt;sup&gt;x&lt;/sup&gt; 6.5&lt;sup&gt;y&lt;/sup&gt; 5.7&lt;sup&gt;x&lt;/sup&gt;</td>
<td>5.8</td>
</tr>
<tr>
<td>Juiciness&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.7&lt;sup&gt;c&lt;/sup&gt; 6.0&lt;sup&gt;cd&lt;/sup&gt; 6.1&lt;sup&gt;d&lt;/sup&gt; 6.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;x&lt;/sup&gt; 5.8&lt;sup&gt;xy&lt;/sup&gt; 6.0&lt;sup&gt;yz&lt;/sup&gt; 6.2&lt;sup&gt;z&lt;/sup&gt; 5.9&lt;sup&gt;yz&lt;/sup&gt;</td>
<td>5.9</td>
</tr>
<tr>
<td>Overall acceptability&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;c&lt;/sup&gt; 5.5&lt;sup&gt;d&lt;/sup&gt; 5.5&lt;sup&gt;d&lt;/sup&gt; 5.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.6&lt;sup&gt;x&lt;/sup&gt; 5.0&lt;sup&gt;xy&lt;/sup&gt; 5.4&lt;sup&gt;yz&lt;/sup&gt; 5.8&lt;sup&gt;z&lt;/sup&gt; 5.1&lt;sup&gt;xy&lt;/sup&gt;</td>
<td>5.2</td>
</tr>
<tr>
<td>Warner-Bratzler Shear (lbs.)</td>
<td>8.6&lt;sup&gt;c&lt;/sup&gt; 8.3&lt;sup&gt;c&lt;/sup&gt; 8.5&lt;sup&gt;c&lt;/sup&gt; 7.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.8&lt;sup&gt;x&lt;/sup&gt; 8.5&lt;sup&gt;x&lt;/sup&gt; 8.6&lt;sup&gt;x&lt;/sup&gt; 7.5&lt;sup&gt;x&lt;/sup&gt; 7.8&lt;sup&gt;x&lt;/sup&gt;</td>
<td>8.4</td>
</tr>
</tbody>
</table>

<sup>a</sup>Marbling degree: PD = practically devoid; TR = traces; SL = slight; SS = small; MT = modest.

<sup>b</sup>1 = extremely undesirable flavor, tough, dry, undesirable; 5 = acceptable; 6 = extremely desirable flavor, tender, juicy, desirable.

<sup>c</sup>,<sup>d</sup>,<sup>e</sup>Means in a row followed by the same letter are not significantly different (P > .05) due to differences in adjusted fat thickness.

<sup>x</sup>,<sup>y</sup>,<sup>z</sup>Means in a row followed by the same letter are not significantly different (P > .05) due to differences in marbling degree.
of marbling. Steaks with a small degree of marbling also had higher scores ($P < .05$) for flavor and juiciness than steaks with traces or practically devoid marbling. Warner-Bratzler shear measurements did not differ ($P > .05$) among marbling degrees, but the steaks with a small degree had the lowest mean shear value.

Correlation coefficients of taste panel palatability traits with cooking losses and quality traits are listed in Table 13. Relationship of tenderness with marbling score was slight ($r = 0.28$) but was negatively correlated with Warner-Bratzler shear ($r = -0.76$). Marbling was more closely related to flavor score than tenderness. Fat color score had a negative correlation with tenderness, thus as fat color became whiter, the longissimus muscle tended to increase in tenderness. Both nonvolatile cooking loss and lean firmness scores were positively correlated with flavor scores. Nonvolatile cooking losses increased as a result of increased fat deposition and lean firmness has also been shown to have a positive relationship with fat deposition. Therefore, increased fat in the carcass results in an improvement in flavor.

Steaks were pooled by quality grades (Table 14) and those from Choice grade carcasses were rated as being more ($P < .05$) tender than steaks from Good and Standard carcasses. Steaks from Choice and Good grade carcasses had similar ratings for flavor, juiciness, and overall acceptability but rated higher ($P < .05$) than steaks from Standard grade carcasses. Choice, Good, and Standard carcasses did not differ ($P > .05$) in shear force values for tenderness.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Flavor</th>
<th>Tenderness</th>
<th>Juiciness</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooking losses:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volatile</td>
<td>0.12</td>
<td>0.11</td>
<td>0.11</td>
<td>0.13</td>
</tr>
<tr>
<td>Nonvolatile</td>
<td>0.45***</td>
<td>0.15</td>
<td>0.30**</td>
<td>0.41***</td>
</tr>
<tr>
<td>Total</td>
<td>0.37***</td>
<td>0.18</td>
<td>0.28*</td>
<td>0.36***</td>
</tr>
<tr>
<td>Marbling degree(^b)</td>
<td>0.42***</td>
<td>0.28*</td>
<td>0.36**</td>
<td>0.41***</td>
</tr>
<tr>
<td>Fat color score(^c)</td>
<td>-0.27*</td>
<td>-0.42***</td>
<td>-0.17</td>
<td>-0.31**</td>
</tr>
<tr>
<td>Lean color score(^d)</td>
<td>0.15</td>
<td>0.18</td>
<td>0.18</td>
<td>0.16</td>
</tr>
<tr>
<td>Lean firmness score(^e)</td>
<td>0.47***</td>
<td>0.15</td>
<td>0.25*</td>
<td>0.45***</td>
</tr>
<tr>
<td>Warner-Bratzler shear</td>
<td>-0.14</td>
<td>-0.76***</td>
<td>-0.34**</td>
<td>-0.38*</td>
</tr>
</tbody>
</table>

\(^a\)Numerical taste panel scores for palatability traits increased as desirability of top loin steaks increased.

\(^b\)Numerical values for marbling increased as marbling degree increased.

\(^c\)Numerical values for fat color decreased as fat color became whiter.

\(^d\)Numerical values for lean color decreased as lean color became lighter red.

\(^e\)Numerical values for lean firmness increased as lean firmness increased.

\(*p<.05\)

\(**p<.01\)

\(***p<.001\)
## TABLE 14
MEANS OF PALATABILITY TRAITS AS AFFECTED BY USDA QUALITY GRADE

<table>
<thead>
<tr>
<th>Variable</th>
<th>Choice (n = 18)</th>
<th>Good (n = 29)</th>
<th>Standard (n = 34)</th>
<th>Overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Palatability traits:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.2</td>
</tr>
<tr>
<td>Tenderness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.8</td>
</tr>
<tr>
<td>Juiciness&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.9</td>
</tr>
<tr>
<td>Overall acceptability&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Warner-Bratzler shear (lbs.)</strong></td>
<td>7.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.4</td>
</tr>
</tbody>
</table>

<sup>a</sup><sup>1</sup> = extremely undesirable flavor, tough, dry, undesirable; 5 = acceptable; 9 = extremely desirable flavor, tender, juicy, desirable.

<sup>b</sup>,<sup>c</sup>Means in a row followed by the same letter are not significantly different (P > .05).
V. CONCLUSION

Percentage of ether extract increased from 0 DOF to 140 DOF while a decrease was observed in moisture percentage of the longissimus muscle. Ether extract was positively correlated with marbling score \(r = 0.84\) and lean firmness \(r = 0.71\). Lean color scores were not related with fat and moisture percentages. Non-volatile cooking loss increased as a result of increased time on feed and was more closely related with carcass fat thickness than marbling degree. Taste panel scores for all palatability traits increased with time on feed with no appreciable change in flavor after 84 DOF. Highest panel scores for tenderness and juiciness were obtained from steaks at 140 DOF. Steaks from steers slaughtered off pasture had a less desirable flavor than steaks from grain-fed steers. Warner-Bratzler shear force measurements did not differ among DOF groups. Warner-Bratzler shear results were closely correlated with taste panel evaluations for tenderness.

Steaks from carcasses with less than 0.2 in. of external fat were rated lower for flavor than carcasses with more than 0.2 in. of fat. Steaks from carcasses with 0.2 in. of fat or less were not significantly different in tenderness from carcasses having more than 0.2 in. of fat. The affect of marbling degree on palatability was not found to be linear and influenced flavor scores more than any other palatability trait. Correlation of fat color scores with palatability traits indicated that as fat color became whiter,
tenderness of the longissimus increased. All palatability traits increased in desirability as carcass quality grade increased and steaks from Choice grade carcasses were rated to be more tender than steaks from Good and Standard grade carcasses. Choice and Good grade steaks were rated higher than Standard grade steaks for flavor, juiciness, and overall acceptability. Therefore, carcasses grading Choice had an advantage in palatability ratings over lower grading carcasses.
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VITA

Henry Walker Stockley, III, son of Mr. and Mrs. H. W. Stockley, Jr., was born March 11, 1959 in Memphis, Tennessee. He graduated from Christian Brothers High School, Memphis, Tennessee, in June of 1977. He enrolled in the College of Agriculture, The University of Tennessee, Knoxville in September of 1977 and received his Bachelor of Science in Agriculture majoring in Food Technology and Science, in August of 1981. In September of 1981 he began to pursue a Master's degree at The University of Tennessee, Knoxville in Food Technology and Science. In March of 1982 he accepted a graduate research assistantship, then in July of 1982 accepted a graduate teaching assistantship in Food Technology and Science and obtained his Master's degree in August of 1983. He is a member of Gamma Sigma Delta and Phi Tau Sigma honor societies, American Meat Science Association and the Institute of Food Technologists professional societies, and is a member of Alpha Gamma Rho Fraternity.