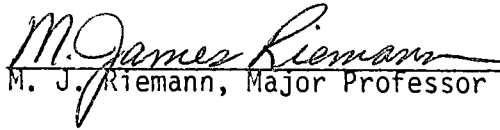
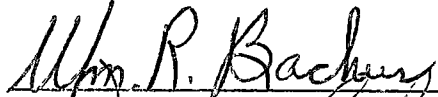
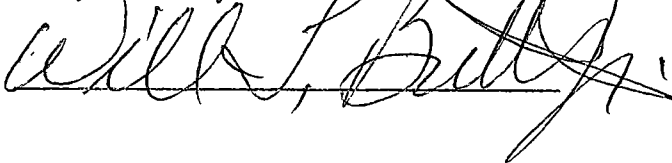


To the Graduate Council:

I am submitting herewith a thesis written by Kathi Lynne Dunn entitled "The Effect of Time on Feed on Certain Physical, Chemical and Sensory Traits of Forage- and Grain-Fed, Serially Slaughtered Angus Steers of Varying Yearling Frame Score Classification." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.


M. J. Riemann, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

THE EFFECT OF TIME ON FEED ON CERTAIN PHYSICAL, CHEMICAL AND
SENSORY TRAITS OF FORAGE- AND GRAIN-FED, SERIALY
SLAUGHTERED ANGUS STEERS OF VARYING YEARLING
FRAME SCORE CLASSIFICATION

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

Kathi Lynne Dunn

March 1982

3057983

DEDICATION

This thesis is dedicated to my parents, Mr. and Mrs. Thomas Sterling Dunn, whose love, guidance, support, encouragement and interest in my life will always be remembered and treasured.

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ABSTRACT

Ninety-one steers grown on winter, spring and summer grass were randomly assigned, within frame size (small, medium or large), to six feeding treatments (pasture only or 28, 56, 84, 112 or 140 days on whole shelled corn fed ad libitum) so the effect of days on feed on certain production, carcass, cookery and chemical characteristics, and the effect of those preceding characteristics upon certain sensory and quantitative descriptors of beef loin steaks could be evaluated.

The slaughter weights increased ($P < .001$) as days on feed (DOF) increased. Rib eye area and hot carcass weight also increased ($P < .001$) as DOF increased. Final mean yield and quality grades were 1.6, low standard; 1.8, high standard; 1.9, high good; 2.6, low choice; 2.8, average choice; and 2.4, average choice. Steers fed to 140 days had a higher dressing percentage (57.31%) than steers slaughtered straight off pasture (51.45%).

Steers fed on whole shelled corn for 140 days were taller at the withers ($P < .001$), had a higher percentage of internal fat ($P < .001$) and revealed a higher degree of marbling ($P < .001$) than steers slaughtered immediately after the pasture stage.

Sensory taste panelists rated loin steaks from the 140 day steers higher on tenderness ($P < .001$), juiciness ($P < .001$), flavor description ($P < .001$), flavor desirability ($P < .001$) and overall desirability ($P < .001$). Warner-Bratzler shear values declined ($P < .01$) for steaks from 140 day steers.

Quantitative descriptive analysis panelists rated loin steaks from the 140 day steers to have a higher intensity of cooked beef fat flavor ($P < .001$) and a lower intensity of milky-oily flavor ($P < .001$).

These data suggest that acceptable quality, yield grades and palatability can be obtained after 84 days of grain feeding.

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CHAPTER I

INTRODUCTION

Meat in the diet historically has been associated with affluence, strength and vitality. Meat's value as a suitable protein source and healthful food cannot be seriously questioned even though consumer advocates concerned about many controversial questions have complicated a relatively simple issue.

There is some disagreement even between animal scientists and from within the packing industry about the future role of beef cattle in feeding a hungry world. "The cost of grain and the cost of money have increased since 1976 to the point of threatening the existence of the cattle-feeding chain as we know it. In short, the well-fed, well-marbled steer providing succulent, savory beef may become as much an artifact of America's consumptive past as the Duesenberg," according to a "Meat Industry" article.

Cattle, being ruminants, have a distinct advantage in being able to utilize foods not suited for human consumption. The drawback is that complete abstinence from grain concentrates produces meat this is not presently acceptable to consumers in the United States.

Cattle, fed primarily grass, usually grade USDA Good or Standard, are less expensive to finish and are leaner cattle. The present consumer demand for leaner beef may enhance the desirability of grass-fed beef. Even so, consumer satisfaction with the palatability traits (tenderness, juiciness and flavor) of cattle finished on grass

alone is very low. This, coupled with a marketing situation where essentially all of the annual production of slaughter beef would be marketed in a short period during late spring and early summer make efficient usage of cool season pastures a deterrent to grass-fed beef production. Further work is needed to substantiate the minimum days on feed required to grain feed a pasture-grown steer of a certain frame score classification to optimize composition, USDA grade, palatability and production traits.

Herein lie the objectives of the present study:

1. To study the effect of ration and time on grain on growth, beef carcass composition and palatability.
2. To study the variation among compact, average and rangy framed cattle fed only on forage and then serially slaughtered at 28 day intervals through 140 days of grain feeding.
3. To determine the effects of time on feed on certain physical, chemical and sensory traits of forage- and grain-fed, serially slaughtered Angus steers of varying yearling frame score classification.

CHAPTER II

REVIEW OF LITERATURE

Production Characteristics

Varying nutritional regimes for growing and/or finishing cattle have been studied extensively in the past. Burson et al. (1980) compared the effects of time on feed and diet energy density to palatability of the longissimus muscle. Studies have also been done on the effects of time on feed on the economic and consumer value of beef production (Tatum et al., 1980; Zinn et al., 1970). Furthermore, body type (frame score) has been examined as a means to predict the time on feed to produce an optimum beef product (Smith and Adams, 1978; Ashfield, 1978; Schlegal, Long and Ramsey, 1980; Dyer, 1980).

Selection for rate of gain and feed efficiency in breeding animals, coupled with consumer demands for leaner beef of high quality, has resulted in a situation which may not be compatible with the most economical production of high quality beef according to Zinn, Durham and Hedrick (1970). In 1977, Clanton stated that sooner or later the supply and demand of beef and feed grains will reach a balance in which grain feeding for finishing cattle will be profitable. In contrast to this, Hodgson (1977) reported that future beef production in the United States will be increasingly dependent on harvested forage, pasture and range.

Predicting carcass quality grade and yield from live animal measurements has been a problem for producers. Black (1938) reported height measured at the wither (with weights held partially constant) is one of the best measures of end performance. Body length, however, had a higher correlation with feed efficiency and average daily gain than did wither height. Rangy Milking Shorthorn steers were found to have lower carcass grades and dressing percentages than did shorter bodied steers which were shorter at the withers and chest (Cook, Kohli and Dawson, 1951).

Green (1954) demonstrated live weight was the single measurement most closely associated with the weights of either the round, loin and rib, or the weights of four major wholesale cuts.

More recent research has been conducted on feeder calf classification (frame and muscling scores) due to the new objectives sought by the beef cattle industry. Several conflicting reports have been submitted concerning the effect of frame size on time on feed. Frame size is a distinguishable characteristic which is supposedly positively correlated with growth rate and ending weight (Tatum et al., 1980). This contradicted an earlier report by Schlegal et al. (1980) who found no significant differences in time on feed to reach the Choice grade between shorter framed cattle and larger framed cattle of the same age after 153, 193 and 255 days on feed. Also, neither rate of gain nor feed efficiency were correlated to frame size. Feeder steers of large, medium or small frame sizes generally have an excellent, average or slow growth rate, respectively (Tatum et al., 1980). Smith et al. (1978) reported USDA quality grades increased

as frame size decreased. Small frame steers on an unlimited grazing regime had a lower average daily gain than did large frame steers, according to Dyer (1980). These reports suggest placing feeder calves in homogeneous groups by frame size would be useful in determining time-on-feed and slaughter weight.

Growth and Development

Muscle, fat and bone are major components of a beef carcass. An ideal carcass consists of a maximum degree of muscling, a minimum of bone and a level of fat suitable to the consumer (Butterfield and Berg, 1976).

The pattern of post-natal development in steers is largely determined by the modifying effects of muscle function on the genetically established pattern of muscle growth (Butterfield and Berg, 1976). Guenther et al. (1965) reported the majority of the potential carcass lean was determined during the early part of the feeding period. Butterfield and Johnson (1971) and Butterfield and Berg (1976) stated muscle proportions of a carcass supposedly do not change with age, but are entirely independent of maturity. Also, in the pre-pubertal stage of growth, there is a large increase in size of the muscle, with proportional weights and function of the muscle staying relatively the same or with very little change (Butterfield and Berg, 1976).

Fat is the most variable tissue in cattle both in amount and distribution. Hiner and Bond (1971) reported a noticeably rapid increase of separable fat when changing cattle from a restricted

diet to full feeding. Guenther et al. (1965) indicated that after cattle reached 205 kg the lean to fat ratio became markedly undesirable. Fat accumulated rapidly during the latter half of the feeding program and lean production began to decrease. Also, Guenther et al. (1965) reported as the animal matures more external fat is accumulated. Genetics and nutrition also affect fat composition of a beef carcass. A heifer tends to have a higher percentage of fat than steers, and the level of nutrition will affect the accumulation of fat proportionately (Butterfield and Berg, 1976). McMeekan (1940) reported the weight of muscles in pigs could be determined within 1% if the weights of the cannon bones could be known. Guenther et al. (1965) reported there was no direct influence on bone development due to the level of nutrition for calves slaughtered at the same age. He also stated bone growth was more closely related to animal age and the number of days on feed. In contrast, comparisons of bone, muscle and fat proportions of beef carcasses made by Waldman, Tyler and Burngardt (1971) showed no significant differences in bone, muscle or fat components of cattle finished on a medium energy diet which restricted weight gain to 60-70% of the weight. Waldman et al. (1971) concluded carcass composition at final weight was not dependent on time required to reach that weight.

Muscle to bone (M:B) ratio has been thoroughly researched in the past as a measure of muscle development and carcass composition. Butterfield and Berg (1976) emphasized that muscle to bone growth proceeds at the same relative rates to each other irrespective of the rate of daily gain as long as positive growth is maintained.

He also reported genetics would affect the M:B ratio. If a beef animal was bred for body thickness and/or for draft purposes, then the M:B ratio would be higher than for dairy animals.

There have been several studies done on muscle to bone ratio as predictors of carcass composition. In 1946, Hankins and Howe correlated the fat and muscle proportions of the 9-10-11th rib section to the percentage muscle and fat in the carcass. Cole, Orme and Kincaid (1960) reported carcass width and round circumference measurements were more highly related to total separable lean. Separable lean of the round accounted for 90% of the variation of the total separable lean. Murphy (1960) developed a universal yield grade prediction equation based on cutability analyses which predict yields of closely-trimmed retail cuts. Ramsey, Cole and Hobbs (1962) stated that yield grade equations omitting rib eye area were more highly correlated to separable fat or lean than when rib eye area was included as part of the prediction equation. Hiner and Bond (1971) demonstrated biceps femoris, psoas major and triceps brachii weights increased in proportion of total lean, the semi-tendinosus stayed at approximately the same proportion of the total lean and the adductor decreased its proportion throughout the growth period. Purchas and Davies (1974) pointed out the 9-10-11th rib section of a grain-fed steer had a significantly higher M:B, coupled with a significantly lower percentage of bone than a pasture-finished steer. Bowling et al. (1978) reported the 9-10-11th rib cut of carcasses finished on greater concentrations of energy to be heavier,

fatter and have a greater muscle mass. Dolezal et al. (1980) used the 9-10-11th rib section to show that M:B ratios differ widely among beef carcasses of similar genetic and management history.

Effect of Breed

Irrespective of breed, 56% of the muscle weight is in the expensive portion of the carcass (rib, loin) (Butterfield and Berg, 1976). Butterfield and Berg went on to suggest that if breeds were to be compared at the same compositional age, their muscle weight distribution would be even more similar. A more recent study by LeVan et al. (1979) showed the percentage of retail cuts produced per day from the round, loin, rib and chuck were greater ($p < .01$) for Charolais versus Angus only in the initial and lightweight groups where the two breeds were more dissimilar. Johnson et al. (1973) compared straight Angus, 3/4 Angus and 1/2 Angus and discovered as the percentage of Angus blood decreased, a significantly linear effect was found with increasing values for carcass weight, rib eye area, and yield grade. Butterfield and Berg (1976) summarized the Angus pattern of fattening: Angus reach a high proportion of subcutaneous to intermuscular fat at relatively low weights of total fat, but then have only a slightly greater impetus of fat growth in the subcutaneous sites.

Sensory Evaluation

Tenderness, juiciness and flavor of meat are palatability characteristics researchers have concentrated on during the past

years. There are many factors which contribute to the final evaluation of a palatability attribute.

Vold (1968) stated as frozen storage time (-20°C) of lamb chops increased tenderness scores increased, and Smith (1969) reported no differences in tenderness ratings between beef steaks cooked from the frozen or raw state. Jakobsson and Bengtsson (1973) found tenderness of beef loin steaks improved as the freezing rate increased. Furthermore, they reported cooking meat directly from the frozen state lowered Instron shear readings, but did not affect sensory tenderness. A weak trend was noticed by Cross et al. (1979) toward increased tenderness of roasted rather than broiled steaks.

Flavor is one of the most important factors to consider when determining whether a sample is acceptable or unacceptable. Desirable beef flavor is difficult to assess as it is affected by several factors. Beef flavor is the result of reactions of non-aromatic precursors during cooking (Black, 1981). Recently evidence has been reported linking beef flavor intensity to the number of days cattle are on feed and their nutritional regime. Therefore, feeding management of cattle prior to slaughter has become a matter of concern for researchers.

Consumer demands for leaner beef, but with high quality, have caused producers and researchers to review extensively the palatability attributes of forage-fed, limited grain-fed and full grain-fed beef. Wanderstock and Miller (1948) compared roasts from grain-fed (ground corn, protein supplement) Hereford steers to forage-fed (bluegrass, white clover) steers. Aroma, fat flavor, lean flavor, juiciness and

tenderness were rated significantly lower for the forage-fed steers. Zinn et al. (1970) reported tenderness increased as days on feed increased for periods up to 180 days. In the Purchas and Davies study (1974), measurements of tenderness favored cereal-fed (grain-fed) steers to approximately 457 kg rather than the pasture-fed steers. Huffman (1974) evaluated 20 mixed-breed steers finished on a combination of rye, ryegrass and arrowleaf clover forage or on grain for 90 days. Trained panelists could not tell any significant differences between the beef produced by the two systems. In a review article, Bidner (1975) summarized that if cattle are fed to a constant weight and grade, the type of diet would have little influence on organoleptic properties. Bowling et al. (1977) demonstrated grain-finished steers were more tender and more desirable in both flavor and overall desirability ($P < .05$). Bowling et al. (1978) placed Santa Gertrudis steers on 10 management systems; calves, yearlings, long-yearlings and 2 year-old steers on diets of grass alone, grain on grass, or placed in a drylot. Sensory panel ratings for flavor desirability were significantly higher ($P < .05$) for grain-fed steers than for forage-only or weanling calves. Tenderness ratings were lower ($P < .05$) for samples from long-yearlings finished on grass and for steers fed grain on grass than for any of the management groups. Juiciness was also rated higher for samples from steers finished only on grain. Cross and Dinius (1978) studied palatability differences in meat from steers fed 105 days on 1) ground alfalfa and orchard grass hay; 2) ground alfalfa; or 3) orchard grass pasture. Laboratory taste panel results showed higher, but non-significant, tenderness,

juiciness and flavor intensity scores for the ground alfalfa and orchard grass hay group and lower tenderness and juiciness scores for steers fed on orchard grass pasture. Steers fed ground alfalfa had the same flavor and juiciness scores, but had higher ($P < .05$) tenderness scores than steers on orchard grass pasture. Harrison et al. (1978) agreed with previous researchers that cattle fed the longest time (98 days) on feed and the highest plane of nutrition (3.11 Mcal ME/kg) had the most desirable palatability attributes. Dyer (1980) serially slaughtered steers every 28 days from 0 days to 140 days on feed (whole shelled corn). General upward trends in both tenderness and flavor ratings were reported. Also, Tatum et al. (1980) slaughtered steers at 100, 130 and 160 days on feed and stated that as days on feed increased from 100 to 160 days, flavor intensity benefitted. Flavor intensity at both 130 and 160 days was significantly different from 100 days, but juiciness, tenderness and overall desirability were not significantly different between treatments.

Carcass Traits

Researchers have sought information on the relationship between an animal's nutritional regime and its final quality and yield grades since the turn of the century. Black et al. (1938) fed 40 steers during the winter (140 days) on corn silage, wheat straw and cottonseed meal. Then half of the steers were placed on bluestem pasture only during the summer (125 days) while the remaining half received bluestem pasture plus a supplement of corn and cottonseed meal throughout the summer grazing period. The researchers

found grain supplemented cattle had higher quality grades at slaughter than cattle fed only grass and lean color of the grain-on-grass cattle was a slightly brighter red than the grass-fed cattle. Bull, Snapp and Rusk (1941) summarized several studies when they reported on pasture-fed only, full grain-fed on pasture and drylot-fed cattle. The steers fed only pasture had a yellower fat color due to the transfer of carotene from grass to body fat and they generally lacked the degree of finish necessary to grade minimum Choice. Furthermore, Bull et al. (1941) stated that cattle full-fed grain on pasture had the same dressing percentage as drylot cattle of the same fat thickness, but tended to have a yellowish fat color. Cattle finished in a drylot, however, had a higher quality grade, a whiter, flakier fat cover and a bright cherry-red colored lean. Wanderstock and Miller (1948) found grass-fed only steers had significantly lower dressing percentages and carcass quality grades than did grain-fed steers. In addition, they reported grain-fed steers (in drylot) had brighter, cherry-red colored rib eyes, higher degrees of marbling and a creamier, whiter fat cover. Forage-fed beef tends to have lower dressing percentage, higher cooler shrink, darker lean color and a lower quality grade (Malphrus, 1957; Guenther et al., 1965).

In the last decade, researchers have once again focused in on grass-fed versus grain-fed cattle. Edwards et al. (1973) reported that steers receiving yellow corn plus corn silage produced a higher degree of marbling, a greater fat thickness and a larger rib eye than cattle on a ration of corn silage only. Bidner (1975) reported

no significant differences in quality grade and yield grade between grain fed (90 days) and grass-fed cattle. Additionally, Bidner (1975) found a slightly yellow fat color in grass-fed cattle. Carcass maturity factors (bone maturity, lean color, lean texture) were more youthful in forage-fed beef than grain-fed beef (Wheeling, Berry and Carpenter, 1975). Skelley et al. (1978) reported that cattle finished with corn silage only produced carcasses which had less marbling than cattle fed a diet of corn silage, urea and corn. Leander et al. (1978) fed Hereford steers on a fescue pasture 180 days, with one group slaughtered directly after pasture, one group slaughtered after being fed a high concentrate diet an additional 56 days and the last group slaughtered after an additional 112 days. Carcass quality grades increased with added days on feed. The former study agreed with Bowling et al. (1978) who stated steers fed grain reached slaughter weight and grade 100 to 230 days sooner and were higher in USDA quality grades than steers finished on forage. Cross and Dinus (1978) said steers fed alfalfa hay versus alfalfa meal had a significantly higher degree of marbling and a whiter fat covering. This agrees with Harrison et al. (1978) who fed steers 98 days in a drylot on a 3.11 Mcal ME/kg ration and got the same results. Also, Harrison et al. (1978) found lean texture tended to be finer the longer cattle stayed on feed. Schroeder et al. (1980) noticed carcasses from all forage diets possessed a darker rib eye muscle. Dyer (1980) reported cattle finished on grain (140 days) tended toward a higher level of external fat and a greater degree of marbling.

Chemical and Histological Characteristics

Wanderstock and Miller (1948) determined the fatter the carcass and the higher the degree of marbling, the smaller the percentage of moisture. Therefore, the lower quality steers would have a higher moisture content.

Howard and Judge (1968) slaughtered 20 Angus steers of approximately the same genetic and nutritional background at a similar live weight (455 kg). After 48 hours postmortem, two samples for fat and moisture were extracted from the loin eye. The mean medial extraction had 7.95% fat and 69.7% moisture, while the mean lateral extraction had 8.54% fat and 69.4% moisture. Waldman and Burngardt (1967) slaughtered Angus steers and heifers at 386, 420 or 454 kg. GLC samples were taken from the rib and significant differences were found for C14, C-16:1, C-18:1 C-18:2 and C-18:3 between the light and heavy weight cattle. However, they did not correlate the fatty acids associated with the longissimus muscle to a specific marbling degree.

The longissimus muscle of 10 Hereford steers fed to 430 kg was used to test the variability in lipid content as related to method of extraction (Marchello et al., 1968). The average ether extract on a moisture free basis was 20.5%, when using chloroform methanol 6.9% total lipids (wet basis) was found, and 23.9% on a dry basis. Large differences were noticed, but the differences were significant ($P < .05$) only when chloroform-methanol was used.

Dikeman and Crouse (1975) concluded carcass chemical composition was not an accurate indicator of meat palatability. They found longissimus muscle chemical fat content increased .27% for each 1% increase in total carcass chemical fat content.

The longissimus muscle of Herefords fed on tall fescue 180 days had 75.35% moisture versus 69.60% moisture for steers full-fed on grain for 112 additional days (Leander et al., 1978). Fat ether extract of the longissimus muscle was 1.91% and 5.51% for the grass and grain-fed steers, respectively. Furthermore, mean sarcomere length for the longissimus muscle for the fescue steers was 1.69, compared to 1.79 for the grain-fed steers.

Cross and Dinius (1978) reported that cattle finished on orchard grass pasture had 11.2% extractable lipids versus 19.5% from steers finished on ground alfalfa ($P < .05$). Skelley et al. (1978) found no significant differences in fat and moisture percentages between the following nutritional regimes: coastal-bermuda grass and yellow corn; urea treated corn silage and cottonseed meal; corn silage, urea and corn; coastal-bermuda grass only. Schroeder et al. (1980) reported that steers fed on native range and forage sorghum (21 days forage sorghum; 56 days on native range; 41 days on native range) had significantly less lipid content ($P < .05$) than steers finished an additional 114 days on grain. Bulgerin et al. (1980) found that the longissimus muscle of forage-fed steers had 7.7% extractable fat and 75.3% moisture, limit-fed steers had 7.3% ether extract and 75.8% moisture and grain-fed steers had 17.9% extractable lipid and 72.4% moisture.

Summary

In summary, increased time on feed is associated with more acceptable palatability, increased carcass maturity, increased fat deposition (external, internal and intramuscular), higher dressing percentages and numerical yield grades and an increased percentage of carcasses grading minimum Choice or better (Guenther et al., 1965; Oltjen, Rumsey and Putnam, 1971; Utley, Hellwig and McCormick, 1975; Lusby, 1977; Bowling et al., 1977; Schroeder et al., 1980; Davis, Cole and Backus, 1980; Dyer, 1980; Tatum et al., 1980).

CHAPTER III

MATERIALS AND METHODS

A total of 185 Angus steer calves, varying in body type, averaging 224 kg were purchased from Tennessee graded feeder calf sales in Crossville, Tennessee and Jamestown, Tennessee. The calves were taken to the Grasslands unit of The University of Tennessee Plateau Experiment Station at Crossville. They were weighed and measurements taken for height and fat thickness. All steers were wintered from November 1979 to April 1980 primarily on a fescue pasture, except when snow covered the ground and hay was fed. On April 14, 1980, prior to the initiation of summer grazing, the steers were randomly weighed, and height and backfat measures were taken. The calves were also wormed and implanted with 36 mg of Ralgro[®] (there was a random sequence for implanting; one was implanted in the ear, one in the muscle and one not at all throughout the 184 steers). The steers were then submitted to unlimited grazing on a pasture of fescue, orchard grass, ladino clover and fescue from April 14, 1980 to August 4, 1980.

When taken off pasture, weights were taken, along with wither height and fat thickness. The calves were also subjectively appraised for frame size, age and estimated finishing weight. At this time 91 steers were assigned to five groups of 15 steers and one group of 16 steers on the basis of frame size.

One group of 15 steers (9 Small's, 4 Medium's, 2 Large's) were transported to Lay's Packing Company, Knoxville, Tennessee for slaughter. The 75 remaining steers were transferred to the 70-N unit of the Plateau Experiment Station at Crossville where they were subjected to a 14-day acclimation period prior to drylot grain feeding. A ration of whole shelled corn was fed ad libitum, along with 1.1 pounds of Tend-R-Leen[®] per head per day.

One group of steers was slaughtered after 28 days on feed and one group every 28 days thereafter through 140 days. All animals continued to be weighed and measured at 28-day intervals.

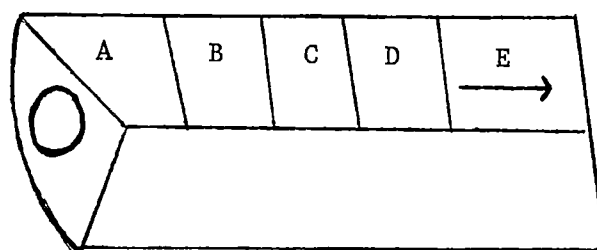
Postmortem Treatment

The carcasses were weighed and chilled for 48 hours postmortem. Each carcass was ribbed and evaluated according to the USDA beef grade standards by a USDA grader and University of Tennessee personnel (Agricultural Marketing Service, 1973). The left side of each carcass was then shipped to The University of Tennessee Meats Laboratory for fabrication according to the procedure of Wellington (1953).

Retail yield was recorded and research samples for muscle to bone determination, sensory, chemical and histological analyses were collected. Muscle to bone analyses were determined by using 1) a ratio of the biceps femoris weight to the femur weight, 2) a ratio of the biceps femoris and the semitendinosus plus adductor weights to the femur and tibia weights and 3) the area of the biceps femoris.

Section A (Fig. 1) (2.5 cm thick) was removed, stripped of all epimysium tissue, frozen in liquid nitrogen and then placed in a Waring blender and powdered. Triplicate powdered samples weighing approximately 2 grams were dried in a vacuum oven at 100°C under a pressure of not more than 100 mg Hg for 5 hours to determine the moisture percentage by weight difference. The samples were then placed in a Soxhlet apparatus and extracted in ether for 16 hours. They were then removed and air dried until all the ether had been evaporated. The samples were then dried in the vacuum oven (100°C) for 3 hours. Fat content was determined by weighing the ether extracted sample and then subtracting this from the dried sample weight. Fat percentage was determined on a wet and a dry tissue basis (AOAC, 1975).

Section B (Fig. 1) (.6 cm thick) was utilized in a fragmentation index study according to a modified Calkins et al. (1980) procedure. Section C, D, E and F steaks were used for shear force, cooking data and taste panel evaluations. The steaks were removed from the freezer 24 hours prior to cooking and thawed at 34°F. All the steaks were broiled in a rotary oven at 350°F to an internal temperature of 72°C. Section C was used for determination of Warner-Bratzler shear values (Bratzler, 1940). Ten 2.5 cm cores were removed after cooling to room temperature after approximately 2 hours, and mean values for maximum kg of force required to shear the cores was recorded. Also, cooking losses, volatile fatty acid and non-volatile fatty acid percentages were calculated. Sensory evaluation (Cross, Moen and Stanfield, 1978), along with a Quantitative Descriptive Analysis (QDA) (Black, 1981), were done on Section D (Fig. 1).



<u>Sample</u>	<u>Thickness (cm)</u>	<u>Measures</u>
A	1.3	Proximate Analysis
B	0.6	Fragmentation Index
C	2.5	W.B.S.: Instron S.F.
D	2.5	Sensory Evaluation
E	2.5	Taste Panel Training and Meat Laboratory

Figure 1. Location of steaks used in laboratory and sensory analysis.

An 11 member (7 minimum) trained panel was used for sensory evaluation. Panelists were served one-half square inch samples from the perimeter of the longissimus muscle. Panelists determined tenderness, juiciness, flavor description, flavor desirability and overall desirability using an 8-point scale (1-very undesirable, 8-very desirable). The QDA panel consisted of 6 trained members who received 2 one-half inch cubes from the center of the longissimus muscle. These panelists evaluated the intensity of milky-oily aroma, beef fat aroma, milky-oily flavor, cooked beef fat flavor, liver flavor, sour flavor and raw flavor of each sample (Black, 1981).

Histological analysis was performed on tissue samples taken from the longissimus muscle at the 12th rib. Samples were prepared and stored in 40% formalin until they were analyzed. Sarcomere length was measured by the method of Locker (1960) using a Wild phase contrast microscope at 150xx with an oil immersion objective and an eyepiece micrometer.

The statistical analysis of this data was conducted in two phases. A regression analysis was conducted in both phases and the independent variables which had a significant influence ($P < .10$) were used in the final model in order to obtain prediction equations for each of the dependent variables. All independent variables which had no significant relationship ($P < .10$) to the dependent variables were deleted from the final model. R-square values were calculated to determine the amount of variation which was explained by the model for each dependent variable.

The dependent variables used in phase 1 of the analysis were the sensory panel and QDA traits of all the loin steaks. The independent variables were selected from various live animal measurements, carcass measurements, cookery data and chemical/laboratory analyses. Partial sum of squares was used to detect those independent variables which were significantly related to the dependent variables in the model and coefficients of partial regression were obtained for the prediction equation.

Phase 2 of the analysis was selection of the best possible model for each of the dependent variables, keeping days on feed, panel member and frame score as fixed effects for each of the models.

CHAPTER IV

RESULTS AND DISCUSSION

The characteristics of the Angus steers utilized in this study are given in Tables 1 and 2. Tables 1 and 2 include means and standard deviations for certain production and carcass traits, respectively.

Mean initial fat thickness (measured ultrasonically) was very similar across the six groups of steers with a range of only 1.5 mm to 2.1 mm. Initial height measurements were also similar across groups and means ranged from 94.7 cm to 96.5 cm. The steers fed grain 56 days had the lightest mean initial weight (214.2 kg) at the beginning of the grain feeding period. Final fat thickness (measured ultrasonically) increased linearly ($P < .001$) to 2.4 mm, 4.2 mm, 7.1 mm, 9.4 mm, 11.2 mm and 11.7 mm for the 0, 28, 56, 84, 112 and 140-day groups, respectively. This concurs with Butterfield and Berg's (1976) summarization of the Angus fattening pattern.

Mean final height measurements (Table 1) were 108.8 cm, 113.3 cm, 113.0 cm, 113.0 cm, 116.6 cm and 117.3 cm, respectively, for the six feeding periods. As was expected, mean final weights increased linearly ($P < .001$) from 312.9 kg (0-day) to 370.3 kg, 402.2 kg, 454.6 kg, 478.8 kg and 500.3 kg for the 28, 56, 84, 112 and 140-day groups, respectively.

The largest single increases (Table 1) in means of final height and weight occurred in the first 28 days on feed (DOF), and the greatest increase in mean fat thickness during a 28-day feeding

Table 1. Means and standard deviations of certain production traits of steers varying in days on feed.

Production Trait	Days on Feed						Overall
	0	28	56	84	112	140	
Initial fat thickness (mm) S.D. ¹	2.1 ±0.9	1.6 ±0.9	1.7 ±1.0	1.9 ±1.0	1.5 ±0.7	1.5 ±0.8	1.7 ±0.9
Initial height (cm) S.D.	95.8 ±1.9	95.2 ±1.5	95.0 ±1.6	96.5 ±1.6	94.7 ±1.4	95.2 ±2.0	95.5 ±1.6
Initial weight (kg) S.D.	224.4 ±42.6	226.2 ±45.6	214.2 ±43.5	225.4 ±33.3	217.3 ±34.0	220.8 ±49.6	221.4 ±41.4
Final fat thickness (mm) S.D.	2.4 ±0.9	4.2 ±1.2	7.1 ±2.5	9.4 ±2.8	11.2 ±2.2	11.7 ±2.4	7.6 ±4.0
Final height (cm) S.D.	108.8 ±2.2	113.3 ±1.5	113.0 ±1.9	113.0 ±2.7	116.6 ±2.5	117.3 ±2.2	114.1 ±2.4
Final weight (kg) S.D.	312.9 ±76.8	370.3 ±106.8	402.2 ±109.9	454.6 ±128.2	478.8 ±87.9	500.3 ±86.3	419.7 ±172.7

¹Standard deviation.

Table 2. Means and standard deviations of certain carcass traits for steers varying in days on feed.

Carcass Trait	Days on Feed						Overall
	0	28	56	84	112	140	
Fat thickness (cm)	2.3	4.6	7.6	10.7	13.8	12.1	8.6
S.D. ¹	±0.1	±0.1	±0.1	-0.2	±0.1	±0.1	±0.2
Rib eye area (cm ²)	53.7	60.8	66.5	68.6	74.9	78.1	67.0
S.D.	±1.1	±1.2	±1.2	-1.4	±0.8	±1.3	±1.7
Hot carcass weight (kg)	160.9	197.3	210.9	244.5	266.4	285.0	227.8
S.D.	±46.6	±59.9	±69.0	-79.5	±55.0	±77.8	±112.8
Internal fat (%)	1.0	1.3	1.0	1.7	2.1	2.4	1.6
S.D.	±0.4	±1.3	±0.3	-0.3	±0.4	±0.4	±0.6
Yield grade	1.6	1.8	1.9	2.6	2.8	2.4	1.6
S.D.	±0.4	±0.4	±0.3	-0.6	±0.5	±0.6	±0.7
Marbling ²	2.7	3.7	4.9	5.8	6.2	6.6	5.0
S.D.	±0.5	±0.6	±1.6	-1.2	±1.2	±1.1	±1.8
Quality grade ³	7.5	9.0	10.9	12.1	12.9	13.1	10.9
S.D.	±0.7	±1.1	±2.1	-1.5	±1.2	±1.2	±2.5

¹Standard deviation.

²1-Devoid, 2-practically devoid, 6-modest.

³7-Low standard, 10-high good, 13-average choice.

period was between 28 and 56 DOF. Average daily gain, not included in Table 1, for the grain-fed cattle was 1.46, 1.70, 1.30, .88 and .45 kg for 28, 56, 84, 112 and 140 DOF, respectively. Feed efficiency, not included in Table 1, was 7.13, 5.61, 6.06, 6.49 and 7.59 for 28, 56, 84, 112 and 140 DOF, respectively.

In both traits (average daily gain and feed efficiency) 56-day cattle rated higher than any other slaughter group. It appears to be uneconomical to feed cattle for 112 or 140 days, as in this study their feed conversion ranged from 9.45 to 19.63 pounds of grain per pound of gain while their average daily gain ranged from only 1.94 to .99. The steers seemed to convert grain to muscle easily at the beginning of the study, while at the end of the feeding trial (140 DOF) they had great difficulty in converting feed to gain. This could be due to a light exposure to shipping fever or the natural slowing down of feed conversion to muscle over time, or a combination of both.

Mean carcass fat thickness (Table 2) increased ($P < .001$) linearly from 2.3 mm at 0 DOF to 12.1 mm at 140 DOF. The greatest increase in mean fat thickness occurred at 56 to 84 DOF and 84 to 112 DOF (3.1 mm increase in each period).

Carcass fat thickness decreased from 112 to 140 DOF (1.7 mm). This is in disagreement with the ultrasonic measure of fat thickness which increased linearly from 0 to 140 DOF. One possible explanation for the variation between the two measures is poor workmanship at the packing plant or human error in either of the measurements.

In previous studies, however, ultrasonic measures have been somewhat lower than the carcass measure between the 12th and 13th rib. Mean rib eye area increased ($P < .001$) for each successive slaughter group from 53.7 cm^2 at 0 DOF to 78.1 cm^2 at 140 DOF. The greatest rate of increase in rib eye area was in the first 28 DOF. This concurs with Guenther et al. (1965) who stated most of the potential muscle is determined during the early stages of the feeding program. Table 2 also shows means of hot carcass weight and percent internal fat for each slaughter group. Mean hot carcass weights increased gradually from 160.9 kg at 0 DOF to 197.3 kg, 244.5 kg, 266.4 kg and 285.0 kg at 28, 56, 84, 112 and 140 DOF, respectively. Only a small increase was observed in mean percent internal fat from 0 DOF (1.0%) to 140 DOF (2.4%). The mean yield grade of each slaughter group increased from 1.6 (0 DOF) to 2.8 (112 DOF), then decreased to 2.4 (140 DOF). Development of both muscle and fat tissues during the first 56 DOF apparently compensated for each other as they relate to the yield grade system because yield grades were 1.6, 1.8 and 1.9 at 0, 28 and 56 DOF, respectively, which indicated a greater proportion of fat than muscle was developed during those periods. The steers fed 140 DOF had a 2.4 carcass yield grade which was the result of a small decrease in fat thickness and an increase in rib eye area of 3.2 cm^2 from 112 to 140 DOF.

Degree of marbling (Table 2) increased ($P < .001$) with DOF, thus beef carcass quality grades increased over time. Mean marbling scores and quality grades for the different slaughter groups were:

0 DOF-practically devoid⁷⁰, low standard; 28 DOF-traces⁷⁰, high standard; 56 DOF-slight⁹⁰, high good; 84 DOF-small⁸⁰, low choice; 112 DOF-modest²⁰, average choice and 140 DOF-modest⁶⁰, average choice.

In this study, a feeding period of only 84 days after steers were removed from pasture produced slaughter cattle that had yield grade 2, choice carcasses. These results disagree with Dyer (1980) who reported steers needed to be fed 112 days on whole shelled corn to produce choice grade carcasses.

Table 3 shows means and standard deviations of different palatability traits of loin steaks as determined by an 11-member trained sensory evaluation panel. The data indicate tenderness, juiciness, flavor description, flavor desirability and overall desirability gradually increased ($P < .001$) with DOF. These results are in general agreement with Oltjen et al. (1971), Kropf et al. (1975) and Dyer (1980).

The tenderness rating for loin steaks increased linearly ($P < .001$) from 5.2 (on a 1-8 scale) at 0 DOF to 6.1 at 140 DOF. Juiciness increased at a decreasing rate over time starting at a 5.1 at 0 and 56 DOF, 5.7 at 84 DOF, 5.5 at 112 DOF and again 5.7 at 140 DOF. Flavor description rating was 4.1 at 0 DOF, 5.1 at 56 DOF and 5.9 at 140 DOF. Flavor desirability increased over time from 4.0 at 0 DOF to 6.0 at 140 DOF. Overall desirability means increased from 4.3 at 0 DOF to 5.9 at 140 DOF. Flavor desirability and overall desirability (which takes into account all palatability attributes)

Table 3. Palatability means¹ and standard deviations of loin steaks for Angus steers varying in days on feed.

Palatability Trait	Days on Feed					Overall	
	0	28	56	84	112	140	Mean S.D. ² C.V. ³
Tenderness S.D.	5.2 ±0.9	5.8 ±1.0	5.5 ±0.8	5.6 ±1.0	5.6 ±0.9	6.1 ±1.1	5.9 1.1 19.4
Juiciness S.D.	5.1 ±0.8	5.2 ±1.0	5.1 ±1.1	5.7 ±1.0	5.5 ±0.8	5.7 ±1.6	6.0 1.1 19.3
Flavor description S.D.	4.1 ±1.6	4.8 ±1.6	5.1 ±1.1	4.8 ±1.3	4.7 ±1.4	5.9 ±0.8	5.2 1.2 24.0
Flavor desirability S.D.	4.0 ±1.5	4.8 ±1.6	5.1 ±1.1	4.9 ±1.3	4.6 ±1.3	6.0 ±0.8	5.3 1.3 23.8
Overall desirability S.D.	4.3 ±1.1	4.9 ±1.2	5.1 ±0.8	5.1 ±1.2	4.8 ±1.1	5.9 ±0.8	5.4 1.2 22.2

¹Measured on a 1-8 point scale; 1=extremely tough, extremely dry, very intense milky-oily flavor, extremely undesirable; 8=extremely tender, extremely juicy, very intense beef fat flavor, extremely desirable.

²Standard deviation.

³Coefficient of variation.

were very highly correlated ($P < .001$) to flavor description with correlation coefficients of .939 and .880, respectively (Table 4).

Coefficients of determination (CD) for multiple regression equations predicting sensory tenderness, juiciness, flavor description, flavor desirability and overall desirability of loin steaks are presented in Tables 5 and 6. This data indicates that days on feed and panel member accounted for 12.87, 21.29, 18.96, 20.57 and 22.86% of the observed variation in sensory tenderness, juiciness, flavor description, flavor desirability and overall desirability. Production traits (final fat thickness--measured ultrasonically, final weight and final height) accounted for 16.56, 24.35, 20.39, 22.24 and 22.23% of the observed variation in the respective traits. Certain carcass characteristics (fat thickness; loin eye area; kidney, pelvic and heart fat; marbling; maturity; lean firmness) explained 19.27, 24.46, 20.74, 23.12 and 24.90%, respectively, of the observed variation in the different sensory traits.

Panelists in this study were served samples from the periphery of the steak. This could explain why there was little variation in sensory tenderness ratings, since according to Covington et al. (1970) who reported Warner-Bratzler shear cores from the periphery of the steak were tougher than inner cores.

CD's for prediction of tenderness rating were 12.73% (days on feed, panel member, fragmentation index) and 13.70% (days on feed, panel member, Warner-Bratzler shear). Warner-Bratzler shear values decreased ($P < .001$) with additional days on feed. Fragmentation index

Table 4. Correlation coefficients between palatability traits used for sensory evaluation of beef loin steaks.

Palatability Trait	Palatability Trait			
	Tenderness	Juiciness	Flavor Description	Flavor Desirability
Tenderness	1.000	.590***	.372***	.424***
Juiciness	.590***	1.000	.389***	.417***
Flavor description	.372***	.389***	1.000	.939***
Flavor desirability	.424***	.417***	.939***	1.000
Overall desirability	.557***	.538***	.880***	.923***
				1.000

***P<.001.

Table 5. Coefficients of determination for multiple regression equations predicting sensory tenderness, juiciness, flavor description, flavor desirability and overall desirability of loin steaks from beef varying in time on feed using fixed effects, production data and carcass measures.

Variables in Subset		Variables ¹	R ² x 100
Tenderness	2	1,3	12.87
	3	1,2,3	13.53
	3	1,3,4	13.01
	4	1,2,3,4	14.00
	6	1,2,3,5,6,7	16.47
	7	1,2,3,4,5,6,7	16.56
	12	1,3,8,10,11,12,13,14,16,17,18,19	19.27

Juiciness	2	1,3	21.29
	3	1,2,3	21.29
	3	1,3,4	21.32
	4	1,2,3,4	21.41
	7	1,2,3,4,5,6,7	24.35
	7	1,3,8,9,15,19,20	24.46

Flavor description	2	1,3	18.96
	3	1,2,3	18.98
	3	1,3,4	19.05
	4	1,2,3,4	19.73
	7	1,2,3,4,5,6,7	20.39
	5	1,2,3,8,9	20.74

Flavor desirability	2	1,3	20.57
	3	1,2,3	21.32
	3	1,3,4	20.74
	4	1,2,3,4	21.34
	7	1,2,3,4,5,6,7	22.24
	7	1,2,3,8,9,13,15	23.12

Overall desirability	2	1,3	22.86
	3	1,2,3	22.86
	3	1,3,4	23.04
	4	1,2,3,4	23.54
	7	1,2,3,4,5,6,7	22.23
	6	1,2,3,8,10,19	24.90

¹Variable code for fixed effects, carcass traits and production

traits

- 1=panel member (fixed effect)
- 2=frame score (fixed effect)
- 3=days on feed (fixed effect)
- 4=days on feed² (fixed effect)
- 5=final weight (production)
- 6=final fat thickness (production)
- 7=final height (production)
- 8=carcass weight (carcass)
- 9=maturity (carcass)
- 10=kidney, pelvic, heart fat (carcass)
- 11=fat color (carcass)
- 12=lean color (carcass)
- 13=marbling (carcass)
- 14=lean firmness (carcass)
- 15=fat thickness (carcass)
- 16=DOF x fat thickness (carcass)
- 17=DOF x marbling (carcass)
- 18=DOF x lean firmness (carcass)
- 19=DOF x kidney, pelvic, heart fat (carcass)
- 20=DOF x fat thickness (carcass)

Table 6. Coefficients of determination for multiple regression equations predicting sensory tenderness, juiciness, flavor description, flavor desirability and overall desirability of loin steaks from beef varying in time on feed using fixed effects, cookery data and chemical analyses.

Variables in Subset		Variables ¹	R ² x 100
Tenderness	3	1,3,5	13.69
	3	1,3,6	12.73
	5	1,3,7,8,9	13.11
	10	1,2,3,5,6,8,9,	
		11,13,14	17.08
	4	1,3,15,16	13.10
	6	1,2,3,4,15,17	14.84
	5	1,2,3,15,17	14.74
Juiciness	5	1,3,7,8,9	21.62
Flavor description	5	1,3,7,8,9	19.07
	6	1,2,3,4,8,13	20.52
	9	1,2,3,18,19,20,21,22,23	20.44
	10	1,2,3,15,18,19,20,21,22,23	20.48
Flavor desirability	6	1,2,3,4,8,13	22.01
	9	1,2,3,18,19,20,21,22,23	22.13
Overall desirability	7	1,2,3,8,9,13,14	24.21
	6	1,2,3,18,19,20	24.17

¹Variable code for fixed effects, cookery data and chemical analyses

- 1=panel member (fixed effect)
- 2=frame score (fixed effect)
- 3=days on feed (fixed effect)
- 4=days on feed² (fixed effect)
- 5=Warner-Bratzler shear (chemical)
- 6=fragmentation index (chemical)
- 7=percentage moisture (chemical)
- 8=percentage fat-wet basis (chemical)
- 9=percentage fat-dry basis (chemical)
- 10=DOF x WBS (chemical)
- 11=DOF x fragmentation index (chemical)
- 12=DOF x percentage moisture (chemical)
- 13=DOF x percentage fat-wet basis (chemical)
- 14=DOF x percentage fat-dry basis (chemical)
- 15=cooking time (cookery)
- 16=degree of doneness (cookery)
- 17=percentage drip loss (cookery)
- 18=percentage volatile cooking loss (cookery)
- 19=percentage non-volatile cooking loss (cookery)
- 20=percentage total cooking loss (cookery)
- 21=DOF x percentage volatile cooking loss (cookery)
- 22=DOF x percentage non-volatile cooking loss (cookery)
- 23=DOF x percentage total cooking loss (cookery)

was not significant with days on feed. It had a correlation coefficient of only $-.230$ with days on feed. More research is needed to perfect this technique since there is considerable human error involved with the procedure which lacks laboratory precision. This is in disagreement with Dyer (1980) who stated the fragmentation index contributes enough information to prediction equations to justify its use as a measure of tenderness of serially slaughtered beef. Predicting sensory tenderness using Warner-Bratzler shear, fragmentation index, percentage fat-wet basis and percentage fat-dry basis accounted for 17.08% of the observed variation, while degree of doneness and percentage drip loss added to the fixed effects accounted for 14.74% of the observed variation.

Data in Table 5 were developed to identify the percentage of observed variation in juiciness which could be accounted for by use of certain combinations of either production or carcass traits. Regression equations for sensory juiciness rating containing only fixed effects (panel member, days on feed) accounted for 21.29%. Only 3.06% (production) to 3.17% (carcass) additional precision was obtained when 5 rather than 2 variables were used to predict juiciness of loin steaks.

CD's for regression equations predicting sensory flavor of loin steaks are shown in Tables 5 and 6. The CD's for flavor were 19.73 (fixed effects) (Table 5), 20.74 (carcass traits plus fixed effects) (Table 5), 20.52 (chemical analyses plus fixed effects) (Table 6), 20.48 (cooking data plus fixed effects) (Table 6) and

20.39% (production parameters plus fixed effects) (Table 5). When all variables were included in a regression model, final live weight influenced flavor description rating ($P<.001$) over all measurable effects.

Means and standard deviations of the quantitative descriptive analysis are presented in Table 7. The intensity and magnitude of milky-oily flavor and beef fat flavor of loin steaks changed significantly ($P<.001$) with days on feed. The concentrations of milky-oily aroma decreased at a decreasing rate from 68.1 mm (based on 150 mm-intense) at 0 DOF to 50.8 mm to 140 DOF. Cooked beef fat aroma increased at a decreasing rate from 55.9 mm at 0 DOF to 53.4 mm at 28 DOF before increasing to 71.9 mm at 140 DOF. The milky-oily flavor decreased at a decreasing rate from 80.6 mm at 0 DOF to 51.4 mm at 140 DOF. Cooked beef fat flavor increased at an increasing rate from 56.8 mm at 0 DOF to 87.8 mm at 140 DOF. Small increases were observed in the intensity of liver, sour and raw flavors. Liver flavor increased from 26.6 mm (0 DOF) to a maximum of 31.6 mm (84 DOF), then decreased slightly to 30.5 mm (140 DOF). Raw flavor increased with days on feed from 27.3 mm at 0 DOF to 32.6 mm at 140 DOF. Sour flavor increased curvilinearly from 33.8 mm (0 DOF) to a maximum of 41.6 mm (112 DOF), then decreased slightly to 39.0 mm (140 DOF).

In contrast to Black (1981) who reported magnitudes of milky-oily aroma and flavor of ground beef at any day on feed were similar, the present study showed more definite linear trends with milky-oily flavor and cooked beef fat flavor than with milky-oily aroma and

Table 7. Quantitative descriptive analysis means¹ and standard deviations of loin steaks from steers varying in time on feed.

Quantitative Descriptor	Days on Feed				Overall			
	0	28	56	84	Mean	S D ²		
Milky-only aroma S D	68.1 ±21.4	66.8 ±20.3	61.2 ±19.3	58.5 ±20.5	55.7 ±18.2	50.8 ±18.8	60.1 20.6	34.2
	55.9 ±18.2	53.4 ±19.3	61.1 ±18.3	66.0 ±17.4	67.7 ±18.3	71.9 ±20.5	64.4 27.0	42.0
Milky-only flavor S D	80.6 ±27.1	81.2 ±29.6	63.9 ±25.4	56.5 ±21.5	54.2 ±20.4	51.4 ±21.0	62.8 19.7	31.3
	56.8 ±23.5	59.5 ±28.7	69.9 ±21.9	83.1 ±20.8	86.1 ±20.6	87.8 ±20.8	74.1 26.0	35.0
Liver flavor S D	26.6 ±15.0	26.2 ±13.3	28.8 ±12.6	31.6 ±13.4	27.8 ±14.7	30.5 ±13.7	28.6 13.9	48.5
	33.8 ±14.6	40.2 ±15.9	39.8 ±14.7	40.7 ±13.6	41.6 ±13.6	39.0 ±11.0	39.2 14.1	36.0
Raw flavor S D	27.3 ±16.3	29.9 ±18.8	27.1 ±16.1	31.3 ±15.6	32.8 ±17.9	32.6 ±16.1	30.2 16.9	55.9

¹Measured on a 1-150 mm scale, 1=slightly intense, 150=extremely intense

²Standard deviation

³Coefficient of variation

beef fat aroma. The QDA panel had a difficult time in assessing scores to loin steaks aroma as compared to ground beef aroma. According to correlation coefficients (Table 8), the undesirable flavor in grass-finished beef may be attributable to the relationship of a more intense combination of a milky-oily aroma and flavor and a much less intense cooked beef fat aroma and flavor. This observation agrees with Black (1981) and Amiri et al. (1980).

CD's for regression equations predicting milky-oily aroma (MOA), beef fat aroma (BFA), milky-oily flavor (MOF), beef fat flavor (BFF), liver flavor (LF), sour flavor and raw flavor of loin steaks are shown in Tables 8 and 9. Panel member and days on feed accounted for 22.97, 25.18, 23.29, 23.72, 8.40, 9.89 and 40.42% of the observed variation in the respective descriptors. Certain production traits (included are final heights, weights and fat thicknesses and initial fat thickness) accounted for 25.85 and 26.23% of the observed variation in milky-oily aroma and beef fat aroma, respectively. Initial fat thickness was significantly different ($P < .01$) when used in predicting MOA. Production measures accounted for 26.74 and 37.49% of the variation of MOF and BFF, respectively (Table 8). Days on feed was found to have a quadratic effect on MOF and BFF with final weight, height and fat thickness, initial fat thickness and a DOF-initial fat thickness interaction.

The best prediction equation for MOA included cookery data (cooking time, percentage volatile, non-volatile and total cooking losses) which explained 27.17% of the explainable variation. BFA

Table 8. Coefficients of determination for multiple regression equations predicting quantitative descriptors of milky-oily aroma, beef fat aroma, milky-oily flavor, beef fat flavor, liver flavor, sour flavor and raw flavor from beef loin steaks from steers varying in time on feed using fixed effects, production data and carcass traits.

Variables in Subset		Variables ¹	R ² x 100
Milky-oily aroma	2	1,3	22.97
	2	3,4	8.24
	3	1,3,4	22.93
	3	1,2,3	23.98
	8	All fixed effects and 5,6,7,8	25.85
	7	All fixed effects and 16,17,21	26.59
Beef fat aroma	2	1,3	25.18
	2	3,4	9.93
	3	1,3,4	25.21
	3	1,2,3	25.18
	7	All fixed effects and 5,6,7	26.23
	6	1,3,13,15,19,20	27.10
Milky-oily flavor	2	1,3	23.29
	2	3,4	18.20
	3	1,3,4	23.87
	3	1,2,3	23.94
	9	All fixed effects and 5,6,7,8,12	26.74
	6	All fixed effects and 13,19	25.80
Beef fat flavor	2	1,3	33.72
	2	3,4	22.03
	3	1,3,4	34.14
	3	1,2,3	33.84
	9	All fixed effects and 5,6,7,8,12	37.49
	7	All fixed effects and 13,14,19	36.72
Liver flavor	2	1,3	8.40
	2	3,4	1.02
	3	1,3,4	8.57
	3	1,2,3	8.40
	7	All fixed effects and 5,6,7	8.81
	3	1,3,18	8.47
Sour flavor	2	1,3	9.89
	2	3,4	2.74
	3	1,3,4	11.53
	3	1,2,3	9.94
	9	All fixed effects and 5,6,7,9,10	13.54
	5	1,2,3,19,22	13.25
Raw flavor	2	1,3	40.42
	2	3,4	1.30
	3	1,3,4	40.42
	3	1,2,3	40.44
	7	All fixed effects and 5,6,7	41.32
	4	1,2,16,17	41.23

¹Variable code for fixed effects, production and carcass

traits	12=DOF x initial fat thickness (production)
1=panel member (fixed effect)	13=fat thickness (carcass)
2=frame score (fixed effect)	14=loin eye area (carcass)
3=days on feed (fixed effect)	15=kidney, pelvic, heart fat (carcass)
4=days on feed (fixed effect)	16=marbling (carcass)
5=final weight (production)	17=lean firmness (carcass)
6=final height (production)	18=maturity (carcass)
7=final fat thickness (production)	19=DOF x fat thickness (carcass)
8=initial fat thickness (production)	20=DOF x kidney, pelvic, heart fat (carcass)
9=DOF x final weight (production)	21=DOF x lean firmness (carcass)
10=DOF x final height (production)	22=DOF x maturity (carcass)
11=DOF x final fat thickness (production)	

Table 9. Coefficients of determination for multiple regression equations predicting quantitative descriptors of milky-oily aroma, beef fat aroma, milky-oily flavor, beef fat flavor, liver flavor, sour flavor and raw flavor from beef loin steaks from steers varying in time on feed using fixed effects, cookery data and chemical analyses.

Variables in Subset		Variables ¹	R ² x 100
Milky-oily aroma	7	All fixed effects and 8,9,10	27 17
	6	1,2,3,5,6,7	24 06
Beef fat aroma.	6	1,3,9,10,11,15	26.80
	5	1,3,4,5,14	26.40
Milky-oily flavor.	7	All fixed effects and 8,9,10	25.73
	8	All fixed effects and 5,6,14,17	27.82
Beef fat flavor	7	All fixed effects and 5,6,14	37 24
	5	1,2,3,4,12	35.22
Liver flavor.	4	1,3,9,12	8 70
	4	1,3,5,6	9.67
Sour flavor	8	1,3,4,9,10,11,13,16	15 19
	7	1,3,5,6,7,14,17	12 02
Raw flavor	5	1,3,9,10,11	41.11
	4	1,3,6,7	40 55

¹Variable code for fixed effects, cookery data and chemical analyses

- 1=panel member (fixed effect)
- 2=frame score (fixed effect)
- 3=days on feed (fixed effect)
- 4=days on feed² (fixed effect)
- 5=percentage moisture (chemical)
- 6=percentage fat-wet basis (chemical)
- 7=percentage fat-dry basis (chemical)
- 8=cooking time (cookery)
- 9=percentage volatile cooking loss (cookery)
- 10=percentage non-volatile cooking loss (cookery)
- 11=percentage total cooking loss (cookery)
- 12=degree of doneness (cookery)
- 13=presteak weight (cookery)
- 14=DOF x percentage moisture (chemical)
- 15=DOF x percentage total cooking loss (cookery)
- 16=DOF x presteak weight (cookery)
- 17=DOF x percentage fat-wet basis (chemical)

variation was explained best (27.10%) using carcass traits (fat thickness; percentage kidney, pelvic and heart fat). MOF was explained best using chemical analyses (percentage moisture and percentage fat-wet basis) to account for 27.82% of the observed variation. CD's for predicting beef fat flavor were highest using production traits (final heights, weights, fat thicknesses and initial fat thickness) to explain 37.49% of the observed variation. Chemical analyses (percentage moisture and percentage fat-wet basis) accounted for 9.67% of the variation in liver flavor. Cookery measures (percentages volatile, non-volatile and total cooking losses and precooked steak weight) accounted for 15.19% of the observed variation in sour flavor. Production traits (final height, weight and fat thickness) accounted for 41.32% of the observed variation in raw flavor. The three preceding statements are the best multiple regression models for that particular descriptor. Other regression equations are shown in Tables 8 and 9.

The highest CD calculated for any descriptor indicated all the fixed effects, plus final heights, weights and fat thicknesses, accounted for 41.32% of the observed variation in raw flavor. Certain carcass characteristics (fat thickness, lean firmness, marbling, loin eye area, maturity and percentage of kidney, pelvic and heart fat) explained 26.59, 27.10, 25.80, 36.72, 8.47, 13.25 and 41.23% of the variation in MOA, BFA, MOF, BFF, LF, sour flavor and raw flavor, respectively. The addition of carcass or production traits

to the fixed effects increased the percentage of variation explained in MOF and BFF 2.51 to 3.45% and 3.00 to 3.78%, respectively.

CHAPTER V

CONCLUSION

In summary, as steers were fed whole shelled corn after being backgrounded on a primarily fescue pasture, the flavor of the loin steaks from the steers changed. In particular, cooked beef fat aroma and flavor increased in intensity and the undesirable milky-oily aroma and flavor decreased in intensity. Also, time on feed was positively related ($P < .001$) to sensory tenderness, juiciness and flavor description. The major change in milky-oily flavor intensity occurred between 28 to 56 DOF, while the major change in beef fat flavor intensity occurred between 56-84 DOF. Tenderness and juiciness was considered acceptable throughout the entire study, while sensory flavor was considered acceptable at 84 DOF, which should not be strictly interpreted to mean that the flavor of beef from steers fed 84 days is desirable, but in this study cattle were considered "finished" at 84 DOF.

Utilizing both the sensory and quantitative descriptive panels from this study indicated that if only beef flavor is considered, the 120-140 day minimum time for grain-finishing steers for market may be reduced to approximately 80 days and the beef flavor would continue to enjoy widespread consumer acceptance.

More research is needed to delve into the correlation between the two taste panels used in this study. Perfecting a combination of the two panels would add more precise data when evaluating

beef loin steaks for research. Also, a complete chemical analysis could be run on the various types of grasses which can be utilized as a forage to determine the cause of the milky-oily flavor which is so undesirable to consumers. More research is also needed to find exactly how long grain must be fed to grass-finished cattle to improve the undesirable flavor of grass-finished beef.

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