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THE EFFECTS OF TIME ON FEED, CARCASS TRAITS AND CHEMICAL MEASURES ON MUSCLING, TENDERNESS AND FLAVOR OF FORAGE- AND GRAIN-FINISHED BEEF

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

William Richard Dyer

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3046795

DEDICATION

This thesis is dedicated to my parents, Mr. and Mrs. Earl Ray Dyer, whose love, guidance, support, encouragement and interest in their children's lives will always be treasured.

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ABSTRACT

Part I: Effect of Days on Feed, Carcass Traits and Chemical Measures on Various Muscle to Bone Ratios from Forage and Grain Finished Steers.

A total of 60 (30 Hereford and 30 Angus) steers varying in body type (frame score 1 to 5) were grouped into 10 sextets according to breed, frame score and feeder calf fat thickness. This basic design created five groups of six Angus and five groups of six Hereford steers. Each group of six was similar in predicted days to reach 12 mm of fat thickness. Ten steers, one steer from each sextet, was slaughtered at six serial slaughter points: 0 (all forage), 28, 56, 84, 112, and 140 days on full feed. Following a 48-hour chill period, carcasses (η=60) were ribbed and evaluated for USDA grade factors and various other measures. Following determination of objective measurements, one round from each carcass was dissected. Tissue separation of the wholesale round resulted in determination of the five measures of muscle to bone ratio: total muscle of round to total bone of round (M:B-1); total muscle of round plus acceptable fat (1.3 cm) to total bone of round (M:B-2); Biceps femoris (BF) to femur (M:B-3); BF plus semimembranosus (SM) and adductor (AD) to femur (M:B-4); and BF plus SM plus AD to femur (M:B-5).

Data indicated that the effects of days on feed, carcass traits and histological measures on carcass muscling of 60 serial slaughtered Angus and Hereford steers are as follows: (1) five measures of muscle to bone ratio were linearly related ($P<.01$) to time on feed; (2) that the predicted value of M:B-1 at 140 days was near the maximum value

usually observed; (3) among five objective measures of muscle to bone ratio, M:B-3 (BF to femur) and/or M:B-5 (BF + SM + AD + to femur + tibia) provided an acceptable objective index for carcass muscling when dissection time and accuracy were both considered; (4) certain carcass traits (weight, adjusted fat thickness and rib-eye area) and histological measures (percentage white fibers, fiber diameter and fat cell diameter) were significantly related to all measures of muscle to bone ratio and to time on feed; (5) an eight variable multiple regression model consisting of two fixed effects, three carcass traits and three histological measures accounted for approximately 61% of the observed variation in M:B-5; (6) fixed effects (breed and time on feed) carcass traits and histological measures accounted for approximately 49, 42, and 22% of the observed variation in M:B-5, respectively; and (7) for a population sample of serial slaughtered steers, fixed effects (time on feed and breed) explained 16 and 31.8% of the variation in M:B-5 not previously accounted for by carcass traits and histological measures, respectively.

Part II: The Effects of Time on Feed, Carcass Traits, and Chemical Measures on Tenderness and Flavor of Forage- and Grain-Fed Beef.

A total of 60 (30 Angus, 30 Hereford) steer calves varying in body type (frame score 1 to 5) were purchased (October, 1979) from Tennessee Graded Feeder Calf Sales and Auction Markets. The cattle were wintered (October to March) on a low energy hay ration. The small framed steers gained 1.12 Kg per day (123.6 Kg total) on forage, whereas the large framed Angus and Hereford steers gained 1.18 Kg per day (144.5 Kg total) during a 122 day limited grazing period (March to August). Following maximum utilization of forage, the 60 steers

were grouped into 10 sextets according to breed, frame score and fat thickness; thus creating five groups of six Hereford steers and five groups of six Angus steers. Each group of six was similar in predicted days to reach 12 mm of subcutaneous fat thickness. Ten steers (one steer from each sextet) was slaughtered at six serial slaughter points: all forage, 28, 56, 84, 112, and 140 days on full feed. Data in this study indicated the following: (1) time on feed was related to sensory flavor and tenderness of the loin steaks; (2) sensory flavor of the semimembranosus was related to time on feed, while tenderness was not; (3) among all physical, chemical and histological measures studied, Fragmentation index accounted for the greatest percentage of variation in sensory tenderness; (4) the fatty acids C14:0, C17:0, C16:1 and C18:1 increased whereas C18:0 and C18:3 decreased with time on feed; (5) sensory flavor rating of loin steaks could be predicted using time on feed, carcass traits, histological or chemical measures.

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PART I

EFFECT OF DAYS ON FEED, CARCASS TRAITS AND CHEMICAL MEASURES ON VARIOUS MUSCLE TO BONE RATIOS FROM FORAGE AND GRAIN FINISHED STEERS

CHAPTER I

INTRODUCTION

Beef consumption is directly related to social conditions, income, and cultural level. The attitudes of meat consumers and merchandisers is directly related to composition, appearance, and to eating satisfaction of the cooked product. In periods of economic stress, consumers may accept products of lower palatability at a lower price.

Consumers have expressed a preference for beef cuts with a high lean to fat ratio with acceptable palatability attributes at a reasonable cost. Thus, the economic challenge of producing lean beef with marginal to acceptable appearance and palatability has stimulated new interest in forage or limited finished cattle.

Detailed studies have indicated that forage-fed beef possesses undesirable quality and palatability traits (Kropf et al., 1975; Bowling et al., 1976; and Brown et al., 1979). These researchers generally conclude that beef slaughtered without adequate grain feeding is unacceptable to the average consumer. Most research to date has dealt with various comparisons of forage- to full grain-finished cattle. Researchers have not fully explained the changes (physical, chemical and histological) which occur during the transition of all forage-finished to grain-finished beef. Factors (fat thickness, carcass weight, l. dorsi area and U.S. yield grade) associated with fat and muscle of carcasses increase with time on feed (Zinn et al., 1962). Cole et al. (1960) reported that separable lean of the carcass

was highly correlated with descriptive measures of carcass length which is known to increase with time on feed. Butterfield and Johnson (1971) indicated that muscle-to-bone ratio of beef was a function of weight not feeding level.

Cole et al. (1964) noted breed and type differences in cattle ranging from short blocky Angus to long, late maturing Holstiens for separation of wholesale cuts into muscle, bone and fat. These studies indicate that as cattle progress in time on feed, weight is increased in the form of muscle, fat, and bone to an "optimum point" at which fat becomes the main contributor of weight gain. This "optimum point" changes with the type, breed, and nutrient level for cattle. Methods designed to predict the point at which muscling and fat optimize in the carcass have been suggested by Butts et al. (1980); Ashfield (1978); and Smith and Adams (1978).

Various muscle-to-bone determinations over time could possibly demonstrate the rate at which muscle, fat and bone develop for background steers and the relationship to the change in carcass measures of fat and muscle. Therefore, the objectives of this study were:

1. To determine the effects of days feed on various muscle-to-bone ratio measurements for carcasses from serial slaughtered steers.

2. To investigate the use of ratios of certain intact muscles to certain bones as an objective index to carcass muscle-to-bone ratio.

CHAPTER II

REVIEW OF LITERATURE

Composition or cutability is reported to be one of the most important carcass characteristics of meat animals (Cole et al., 1964). Extensive research has been conducted in the area of predicting carcass lean and yield with use of selected carcass traits. The most extensively used muscle for estimation of carcass muscling is the l. dorsi. Palsson (1939) demonstrated that degree of muscle development could be predicted by a cross-sectional area of the l. dorsi muscle at the last rib. McMeekan (1941) expanded the idea with a "shape index" (length/depth of l. dorsi x 100) to predict carcass composition. Hooper (1944) and Hankins and Howe (1946) related composition of the 9-10-11th rib section to total composition of the carcass. Cole et al. (1960) reported that weight of the l. dorsi accounted for 18% of total variation in carcass lean. Butterfield (1965) stated that weights of individual and/or groups of muscles and bones could be used for predicting carcass composition. The reasoning for this theory was explained in a later paper in which Butterfield and Berg (1966) stated that muscles grow and develop in concert. Further studies demonstrated that differences in muscle development could be explained by the function of the anatomical muscle groups. It was also concluded that changes in muscle development are completed prior to slaughter of the mature animal (Butterfield and Berg, 1963b; Butterfield and Berg, 1966; Lohse et al., 1971; Butterfield and Johnson, 1971; and Johnson, 1974). The use of weights of certain muscles and bones, muscle and bone groups

and simple carcass cuts to predicted carcass composition have been used by several researchers (Orme et al., 1960; Cole et al., 1960; Cole et al., 1962; Callow, 1962; Harrington and King, 1963; Epley, 1971; and Butterfield and Johnson, 1971). Cole et al. (1960) reported carcass muscling was highly correlated to descriptive measures of carcass dimension and weight along with separable lean of particular beef cuts. Harrington and King (1963); Butterfield and Johnson (1971); Nelms et al. (1970); and Johnson (1974) reported similar results. Butterfield (1962, 1963a, 1963b); and Lopez (1976) reported that weight of muscle and bone in the foreshank of cattle was useful in predicting total carcass composition. Cole et al. (1960) reported dissection of the round into fat, muscle and bone was the best predictor of carcass lean (the round was correlated at .95 with total carcass cut out). Studies demonstrating the effect of nutritional plane on carcass composition have shown conflicting results. Guenther et al. (1965) reported that muscle growth was greater in calves fed on a high plane of nutrition than those on a moderate plane. Zembayashi and Dake (1978) reported significant differences for muscle to bone ratio among cattle fed on different levels of nutrition (holding time constant). They stated that cattle fed at high or medium-high nutrition levels had higher muscle to bone ratios than cattle fed at low or medium-low levels. However, Callow (1962), Hendrickson et al. (1965) and Waldman (1965) found no significant effects caused by nutritional level.

Wide variation in intramuscular fat has been demonstrated by Callow (1962) and Johnson et al. (1973). Research by Johnson and Pryor (1979) and Suess et al. (1969) indicate that intramuscular fat

had no significant effect on muscle to bone ratio. Fat thickness has been useful as a predictor of carcass composition and yield (Cole et al., 1960; Murphey et al., 1960; Ramsey et al., 1962; and Johnson et al., 1972). Zinn et al. (1962) reported that fat distribution was a function of breed and degree of fat finish of the carcass. This is in agreement with Johnson (1974) and Cole et al. (1964). Cole et al. (1964) reported differences in the amount of bone between breeds with Angus and Hereford breeds having the least and Holstein and Jersey the greatest amount of bone. Bone ranges from 40% in the foreshank to 1% in the flank of the animal. Bone comprises an estimated 16% of total carcass composition and has been shown to vary the least when compared to muscle or fat (Cole et al., 1964; Butterfield 1965; and Butterfield and Johnson 1971).

CHAPTER III

EXPERIMENTAL PROCEDURE

Basic Design

A total of 60 (30 Angus and 30 Hereford) steer calves varying in body type were purchased from Tennessee Graded Feeder Calf Sales and Auction Markets. The 60 cattle were grouped into 10 sextets according to breed, frame score and initial feeder calf fat thickness, thus creating 5 groups of 6 Hereford steers and 5 groups of 6 Angus steers (Table 1). Each group of 6 was similar in predicted days to reach 12 mm of subcutaneous fat.

All steers (n=60) were wintered (October to April, 1979) on a low energy stockpiled pasture and hay ration at the Plateau Experiment Station, Crossville, Tennessee. All steers were assigned to unlimited grazing on an orchard grass (IRN 2-03-451), Kentucky 31 fescue ((RN 2-01-902), and Ladino clover (IRN 2-01-902) pasture from April 1979 to July 30, 1979. All steers were weighed, somoscoped for fat thickness, wormed, implanted with Rolgrow, and re-evaluated for frame score and body type by one experienced selector on July 31, 1979. Comparisons were made intragroup and a limited number of steers were reassigned a feeder calf score, although randomized groups were not changed. On July 31, 1979, 10 steers (one from each of the 10 sextets days on feed) were slaughtered at The University of Tennessee Meat Laboratory. The remaining 50 steers (5 steers from 10 sextets) were placed on a 100% concentrated ration (ground shelled corn, IRN 4-02-931, and Tend-R-Lean) with dicalcium phosphate (IRN 6-01-080) and trace

Table 1. Basic Animal Design (n=60)

Group No.	Breed		Days on Feed	Slaughter Date (1979-80)
	Angus	Hereford		
1	5	5	0	July 31
2	5	5	28	September 11
3	5	5	56	October 9
4	5	5	84	November 6
5	5	5	112	December 4
6	5	5	140	January 2

mineral salts for 14 days to allow acclimatization and then 10 steers per point were serially slaughtered at 5 points (28, 56, 84, 112 and 140 days) after that time.

Postmortem Handling

Following a 48-hour chill in a 1 C cooler with good air velocity, each carcass was ribbed and evaluated according to the USDA beef grade standards (USDA, 1976) by an experienced selector for quality and yield grade factors. Subjective evaluations for the following quality indicators were also performed: lean color; lean texture; lean firmness; marbling distribution; marbling variability; and marbling texture (for each indicator, respectively, on an 8 unit scale: 8 = light grayish pink, very fine, very firm, very uniform, very uniform size, very fine; 1 = black, very coarse, very soft, very uneven, extremely variable in size, very coarse). Additional scores and measures are as follows: fat color (5 unit scale: 5 = very white, 1 = yellow); muscling score (5 unit scale: 5 = thick, 1 = thin); meatiness score (5 unit scale: 5 = very meaty, 1 = lacks meatiness); width of l. dorsi (distance from the dorsal edge to ventral edge, through the geometrical center, of the l. dorsi); length of l. dorsi (distance from dorsal edge to lateral edge, through the geometrical center, of the l. dorsi); carcass length (anterior edge of aitch bone to anterior edge of the first rib); thorax depth (ventral edge of fourth sternum vertebrae to dorsal spinous process); and body wall thickness (the thickness of the body wall measured at a point 5.1, 10.2, 15.2 cm, respectively, lateral to the lateral edge of the l. dorsi muscle.

Carcass Fabrication

The hindquarter of the left sides of the carcasses ($n=60$) was separated into flanks, sirloin short-loins and rounds. The rounds were removed from the carcass (left side) through the 4th and 5th sacral vertebrae and 3.5 cm anterior to the edge of the aitch bone. The short-loin was separated from the flank according to procedures of Wellington (1953). The short-loins were wrapped in poly vinyl choride and placed in a 1 C cooler for a 10 day aging period. The rounds were weighed and prepared for dissection.

Round Measurements

The round was measured for width of exposed lean in the round face (lateral edge of tensor fasciae latae to lateral edge of biceps femoris); depth (the distance from the aitch bone perpendicular to the outside round passing through the anterior end of the exposed femur); and length (the posterior end of the round at the stifle joint to the exposed medial tip of the ischium in the exposed round face). Geometric center for subcutaneous fat depths of fat over the inside and outside round were also recorded.

Dissection Procedure

Immediately following determination of objective measurements, the round was separated into 3 major components (muscle, fat and bone) according to the procedures of Cole et al. (1960). Muscles were weighed in 4 groups: total muscle of the round, biceps femoris, semimembranosus, and adductors. Bone weights were separated into 3 groups: total bone and major connective tissues, femur, and tibia.

The subcutaneous and intermuscular fat of the round was segmented into 3 groups as follows: a) inside round fat (subcutaneous), b) outside round, and c) intermuscular. Total fat was a combination of outside, inside, seam and fat removed from the shank.

Muscle to Bone Determination

Following separation of tissues into muscle, fat and bone, several muscling endpoints were determined. The endpoints are as follows:

M:B-1 = total muscle of round to total bone of round

M:B-2 = total muscle of round plus acceptable fat (1.3 cm) to total bone of round.

M:B-3 = biceps femoris (BF) to femur.

M:B-4 = (BF) plus semimembranosus (SM) and adductor (AD) to femur.

M:B-5 = BF plus SM and AD to femur and tibia.

Statistical Analysis

Statistical analysis was achieved by use of the Statistical Analysis System (Barr et al., 1979). Means, standard deviation, coefficients of variation, partial correlation coefficients and multiple regression analysis were performed according to Snedecor and Cochran (1967).

CHAPTER IV

RESULTS AND DISCUSSION

Data presented in Table 2 are overall means, standard deviations and coefficients of variation values for selected carcass measures (stratified according to breed and slaughter time). These data indicate that Angus possessed larger ($P<.05$) slaughter and carcass weights, and U.S. yield grade numbers than Hereford cattle. No breed differences ($P<.05$) were noted for carcass length, thorax depth, or any of the three *l. dorsi* muscle measures. All carcass measures related to weight, U.S. yield grade and carcass quality showed a positive linear increase ($P<.01$) across days on feed. This is in general agreement with Cole et al. (1962); Callow (1962); Berg and Butterfield (1966); and Lopez (1976).

Mean values for carcass quality traits are presented in Table 3. Marbling degree, quality grade, lean color and lean firmness all increased ($P<.01$) linearly across time on feed. This is in agreement with Zinn et al. (1961) and Dinius and Cross (1978). Sarcomere length, fiber diameter, fiber area and percentage fat (MFB) also increased ($P<.01$) across days on feed (see page 48). The increase in sarcomere length may have been the result of cold shortening which occurs with muscle covered with a limited degree of subcutaneous fat. This is in agreement with Smith et al. (1976).

Data presented in Table 4 are mean values for certain measures of muscle to bone ratio (stratified for breed and across days on feed). These data indicate that significant breed differences ($P<.001$) were

Table 2. Mean Values for Carcass Measures for Steers Varying in Days on Feed

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
						Slaughter Weight (kg)			
Angus	438.4	68.6	15.7	356.1	382.2	423.2	448.1	505.7	515.3
Hereford	416.2	77.5	18.6	337.0	370.4	421.7	390.5	458.9	518.8
All	427.3	73.5	17.2	346.5	376.3	422.5	419.3	422.3	517.0
						Carcass Weight (kg)			
Angus	262.0	52.6	20.11	189.6	223.1	245.7	272.4	313.7	324.1
Hereford	245.8	57.9	18.6	181.0	213.7	243.6	243.6	284.3	321.6
All	253.9	55.5	21.8	185.3	218.5	246.1	251.4	299.0	322.9
						Carcass Length (kg)			
All*	118.6	5.3	4.5	113.8	114.3	113.6	119.9	122.4	123.2
						Thorax Depth (cm)[c]			
All*	56.6	3.0	5.5	54.4	56.9	55.6	56.6	57.9	58.2
						L. dorsi Muscle Area (cm^2)			
Angus	65.8	10.3	15.6	55.5	60.0	60.6	65.8	74.8	76.8
Hereford	61.9	12.9	21.1	52.9	54.2	58.1	58.1	73.5	75.5
All	63.9	11.6	18.5	54.2	57.4	59.4	61.9	74.2	76.1
						US Yield Grade			
Angus	3.0	0.7	24.1	1.9	2.6	3.3	3.1	3.1	3.7
Hereford	2.7	0.8	29.2	1.9	2.2	2.8	2.7	2.9	3.9
All	2.8	0.8	26.7	1.9	2.4	3.0	2.9	3.0	3.8
						Length of L. dorsi (cm)[d]			
All*	13.0	0.8	6.2	12.7	12.7	12.7	13.0	13.2	13.5

Table 2 (continued)

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	24	56	84	112	140
				Width of L. dorsi (cm)[e]					
All*	5.8	0.8	13.2	5.3	5.3	5.6	5.6	6.4	6.4

*No breed difference ($P < 0.05$)

[a]SD = standard deviation

[b]CV - coefficient of variation

[c]Thorax depth = length from ventral edge of fourth sternum vertebrae to dorsal edge of the fourth spinous process

[d]Length of area = distance from proximal edge to distal edge (through the geometric center) of L. dorsi muscle

[e]Width of eye = distance from medial edge to lateral edge (through geometric center) of L. dorsi muscle

Table 3. Mean Values for Quality Indicators of Carcass Produced from Steers Varying in Days on Feed

	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
				Marbling Degree[c]					
Angus	12.5	3.6	28.7	8.4	11.6	11.0	12.8	14.2	17.0
Hereford	10.6	3.4	31.9	7.0	9.4	10.4	9.2	12.2	15.4
All*	11.6	3.6	81.1	7.7	10.5	10.7	10.9	13.2	16.2
				US Quality Grade[d]					
All*	10.2	2.1	20.6	7.7	9.6	10.2	10.1	11.6	12.7
				Marbling Texture[e]					
All*	5.5	1.4	25.1	---	5.7	5.8	5.2	5.3	5.4
				Marbling Variability[e]					
All*	5.0	2.1	42.3	---	5.7	4.9	3.2	5.4	5.6
				Marbling Distribution[e]					
All*	6.0	1.5	24.5	---	6.6	6.2	5.3	5.6	6.4
				Lean Color[f]					
All*	5.1	1.4	26.9	4.5	4.5	5.5	4.5	5.6	5.8
				Lean Texture[f]					
All*	4.9	1.5	33.4	4.0	5.0	4.3	3.3	5.5	5.2
				Lean Firmness[f]					
All*	5.9	1.5	24.6	5.3	5.5	6.0	6.4	6.6	5.8
				Overall Maturity[k]					
All*	16.5	1.62	10.1	15.4	15.4	15.7	17.0	16.2	16.6

Table 3 (continued)

[a]SD = standard deviation

[b]CV = coefficient of variation

[c]Marbling degree = 30 unit scale: 30 = AB^{+}, 1 = D^{-}.

[d]Quality grade = 17 unit scale: 6 = STD^{-}, 17 = P^{+}.

[e]8 = very fine, very uniform, very uniform size; 1 = very coarse, very uneven, extremely variable size, for marbling texture, marbling variability and marbling distribution, respectively.

[f]8 = light grayish red (pink), very firm, very fine; 1 = black, very soft, very coarse, for lean color, lean firmness and lean texture, respectively.

[k]Overall maturity = A^{00} = 10, A^{50} = 15, A^{100} = 20.

Table 4. Mean Values for Certain Measures of Muscle to Bone Ratio

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
						M:B-1[c]			
Angus	3.77	0.45	11.8	3.25	3.85	3.58	3.96	4.02	4.04
Hereford	3.40	0.37	11.0	3.08	3.01	3.59	3.48	3.62	3.60
All	3.58	0.45	12.6	3.17	3.44	3.59	3.69	3.82	3.82
						M:B-2[d]			
Angus	4.61	0.72	15.6	3.84	4.15	4.39	4.46	5.23	5.56
Hereford	4.37	0.75	17.1	3.67	3.89	4.39	4.18	4.83	5.31
All	4.49	0.73	16.4	3.76	4.02	4.39	4.31	5.09	5.44
						M:B-3[e]			
Angus	2.86	0.35	12.1	2.57	2.81	2.59	2.99	2.83	3.31
Hereford	2.50	0.32	13.0	2.31	2.23	2.56	2.39	2.70	2.75
All	2.68	0.37	14.1	2.49	2.54	2.37	2.69	2.77	3.05
						M:B-4[f]			
Angus	5.56	0.60	10.9	5.08	5.51	5.11	5.69	5.59	6.40
Hereford	4.90	0.53	10.9	4.68	4.54	4.98	4.72	5.24	5.25
All	5.23	0.66	12.5	4.88	5.03	5.04	5.20	5.42	5.82
						M:B-5[g]			
Angus	2.41	0.36	10.7	3.11	3.88	3.10	3.52	3.52	3.84
Hereford	3.04	0.32	10.6	2.86	2.81	3.05	2.94	3.27	3.30
All	3.22	0.40	12.1	2.99	3.10	2.07	3.23	3.40	3.57

Table 4 (continued)

[a]SD = standard deviation

[b]CV = coefficient of variation

[c]Muscling (M:B-1) = total muscle of round to total bone of round

[d]M:B-2 = total muscle + acceptable (1.5 cm) fat to total bone

[e]M:B-3 = Biceps femmoris (BF) to femur

[f]M:B-4 = (BF) + semimembranous (SM) + adductor (AD) to femur

[g]M:B-5 = (BF) + (SM) + (AD) to femur and tibia

noted for all measures of muscle to bone studied. Angus steers possessed higher muscle to bone ratio values than Hereford cattle. Perhaps the Angus steers matured at a faster rate and/or performed on the full concentrate grain ration to a higher degree than Hereford steers (E. R. Lidvall, personal communication). Berg and Butterfield (1966) indicated that total carcass lean is primarily a function of carcass weight. This may partially explain the differences between breeds since Herefords had lower carcass weights as previously discussed. A linear increase ($P<0.01$) was noted for all measures of muscle to bone across days on feed. This is in agreement with Berg and Butterfield (1966) who reported that muscle to bone increased with fatness of the carcass. Cole et al. (1962) also stated that carcass weight and fat thickness had more influence on muscle to bone than any other carcass traits. In a calf study, Butterfield and Johnson (1971) indicated muscle to bone ratio was a function of weight and not feeding level.

Simple correlation coefficients relating different measures of muscle to bone ratio with and without the breed effect are presented in Table 5. These data indicate significant correlation values between all measures of muscle to bone ratio which is in general agreement with Butterfield (1965); Berg and Butterfield (1966); Cole et al. (1960); Butterfield and Johnson (1971); and Lopez (1976). The muscle to bone measures shown in Table 5 can be grouped as follows: M:B-1 and M:B-2 are highly correlated ($r=.97$) and can be considered as group 1, while the second group (M:B-3, M:B-4 and M:B-5) was also highly correlated ($r=.97$). Correlation values between measures of muscling in groups 1 and 2 range between $r=.69$ and $r=.75$ (Table 5).

Table 5. Simple Correlation Coefficients Relating Different Measures of Muscle to Bone Ratio to Each Other

Types	Types of Muscle to Bone Ratio M:B-1	M:B-2	M:B-3	M:B-4	M:B-5
M:B-1	--	.97**	.68**	.71**	.75**
M:B-2		--	.69**	.71**	.74**
M:B-3			--	.97**	.97**
M:B-4				--	.97**
M:B-5					--

*P < 0.05

**P < 0.01

Thus all measures of muscle to bone utilized in the present study appear to provide an acceptable index of carcass muscling. Muscle to bone of wholesale cuts (round, chuck and 9-10-11th rib section) are well documented as an excellent predictor of total composition of the carcass (Orme et al., 1960; Cole et al., 1960; Cole et al., 1962; Callow, 1962; Harrington and King, 1963; Epley, 1971; Butterfield and Johnson, 1971; and Lopez, 1976).

Considering dissection time, accuracy and economic loss, the determination of muscle to bone using only the BF and femur (M:B-3) or three large muscles and two intact bones (M:B-5) provided a relatively simple objective index to carcass muscling. This is supported by Butterfield (1966).

Data presented in Table 6 are simple correlation coefficients relating different measures of muscle to bone ratio with certain physical and histological traits. These data indicate that measures of carcass fat (fat thickness; percentage kidney, pelvic and heart fat; body-wall thickness of 5.1 cm; marbling degree), weight and muscling (rib-eye area and width of eye) were all correlated ($P<.001$) with all five measures of muscle to bone. This is in general agreement with Cole et al. (1962) and Zembayashi and Dake (1978).

Histological measures (fiber diameter and fiber area) were not significantly correlated with four measures of muscle to bone ratio. These traits were related ($P<.05$) to M:B-5. These low relationships are partially a result of the histological data being collected from 1. dorsi muscle. This appears to agree with Cole et al. (1960) who stated that measures from the loin accounted for only 18% of the total

Table 6. Simple Correlation Coefficients Relating Different Measures of Muscle to Bone Ratio with Certain Physical and Histological Traits

Trait	M:B-1	M:B-2	M:B-3	M:B-4	M:B-5
Carcass weight	.51**	.52**	.58**	.55**	.59**
Carcass length	.04	.05	.20	.15	.15
Thorax depth	-.05	-.01	.04	.02	.04
Fat thickness	.57**	.62**	.51**	.50**	.56**
Percentage KPH	.60**	.65**	.58**	.56**	.58**
Body-wall thickness	.64**	.66**	.61**	.59**	.65**
Marbling degree	.61**	.62**	.58**	.58**	.58**
Lean color	.49**	.50**	.41**	.43**	.45**
Rib-eye area	.45**	.44**	.54**	.54**	.59**
US yield grade	.55**	.61**	.49**	.46**	.50**
Length of l. dorsi	.49**	.47**	.53**	.52**	.56**
Width of l. dorsi	.49**	.47**	.53**	.52**	.56**
Conformation score	.66**	.67**	.64**	.64**	.69**
Meatiness score	.21	.13	.27*	.29**	.30**
Fiber diameter	.08	.03	.21	.20	.27*
Fiber area	.06	.03	.19	.19	.25*

*P < .05

**P < .01

variation of separable lean in the carcass. West (1974) noted that percentage white fiber of the loin was useful in predicting muscling of the carcass.

Measures of carcass length and thorax depth were not related ($P<.05$) to measures of muscle to bone. This is in disagreement with Cole et al., 1960; Cole et al., 1964; and Zinn et al., 1962, however this was probably due to small age and breed differences (i.e., beef versus dairy types).

Data presented in Table 7 are coefficients of determination for muscle to bone measures using certain round measures. These data indicate that use of round weight and outside fat of round accounted for 26.46, 30.08, and 31.94% of the observed variation in M:B-1, M:B-3 and M:B-5, respectively. The use of the full six variable model only explained an additional 1.5 to 5.3% variation in M:B ratio over the two variable model.

Data presented in Table 8 are coefficients of determination for muscles to bone measures using carcass characteristics and fixed effects. The variables were selected from extensive regression and correlation analyses and based on logic to provide the best possible predictors. Regression equations using fixed effects (FE, variables 1 and 2) could explain 44.03, 45.57, and 49.44% of the variation found in M:B-1, M:B-3, M:B-5, respectively. Carcass characteristics also explained about 45% of the variation in muscling. FE and carcass traits combined increased the explained variation by 8.6 to 14.3% (Table 8). These data indicated that carcass characteristics and fixed effects employed similar parameters to predict muscle to bone ratio. A study of the sum of square analysis (not presented in tabular

Table 7. Coefficients of Determination for Multiple Regression Equations Predicting Muscle to Bone Ratio for Beef Varying in Time on Feed

Variables in Subset	Variables[a]	R^2 x 100	SEE[b]
	Certain Round Measurements		
		M:B-1	
2	1,5	26.46	.37
3	1,4,5	26.46	.37
4	1,4,5,6	27.38	.36
6	Full Model	27.97	.37
		M:B-2	
2	1,5	24.49	.44
3	2,3,5	29.19	.44
4	2,3,4,5	29.44	.44
6	Full Model	29.83	.44
		M:B-3	
2	1,5	30.08	.32
3	1,4,5	32.80	.32
4	1,4,5,6	33.03	.32
6	Full Model	33.10	.33
		M:B-4	
2	1,5	28.58	.56
3	1,4,5	30.70	.55
4	1,2,4,5	31.67	.55
6	Full Model	31.69	.57
		M:B-5	
2	1,5	31.94	.32
3	1,4,5	34.49	.32
4	1,2,4,5	35.27	.32
6	Full Model	35.97	.32

[a]Variable code for measurements of the beef round:
1 = weight
2 = depth
3 = width
4 = length of cushion
5 = subcutaneous fat (outside of round)
6 = subcutaneous fat (inside of round)

[b]SEE = standard estimate of error.

Table 8. Coefficients of Determination for Multiple Regression Equations Predicting Muscle to Bone Ratio for Beef Varying in Days on Feed

Variables in Subset	Variables[a]	R^2 x 100	SEE[b]
	Carcass Characteristics		
	M:B-1		
2	1,2	44.03	.35
3	2,4,6	50.36	.32
5	2,4,5,6,7	52.42	.32
7	Full Model	53.28	.33
2	6,7	44.30	.34
3	5,6,7	46.48	.34
5	All except 1,2	47.06	.35
	M:B-2		
2	1,2	43.49	.41
3	2,3,5	50.87	.37
5	1,2,4,5,6	52.78	.37
7	Full Mcdel	52.92	.38
2	3,6	46.41	.39
3	5,6,7	50.58	.39
5	All except 1,2	52.00	.39
	M:B-3		
2	1,2	45.57	.40
3	2,3,5	50.86	.27
5	1,2,4,5,6	52.78	.27
7	Full Model	59.91	.28
2	3,6	38.13	.30
3	3,6,7	40.50	.30
5	All except 1,2	41.07	.31
	M:B-4		
2	1,2	44.29	.49
3	2,4,5	52.23	.49
5	2,4,5,6,7	53.67	.47
7	Full Model	53.85	.47
2	6,7	39.00	.52
3	4,6,7	41.10	.51
5	All except 1,2	41.98	.52

Table 8 (continued)

Variables in Subsets	Variables[a]	R^2 x 100	SEE[b]
		M:B-5	
2	1,2	49.44	.28
3	2,4,5	57.34	.26
5	1,2,4,5,6	57.81	.26
7	Full Model	58.00	.27
2	4,5	41.59	.30
3	4,6,7	44.71	.30
5	All except 1,2	46.28	.31

Note: Regression equations above the line were calculated with fixed effects. Regression equations below the line were calculated without fixed effects.

[a]Variable code for carcass characteristics and fixed effects:
1 = days on feed
2 = breed
3 = carcass weight
4 = rib-eye area
5 = fat thickness
6 = marbling degree
7 = lean color

[b]SEE = standard estimate of error.

form) indicates a reduction in the sum of squares for time on feed with addition of selected carcass traits (adjusted fat thickness, rib-eye area and marbling degree). Thus carcass traits used to predict muscling of the carcass are directly related to days on feed. Breed effect sum of squares were only slightly affected, indicating that the variation caused by breed is independent of days on feed.

Although breed differences have been documented (Cole et al., 1964 and Butterfield and Johnson, 1971), most research studies show little difference between the Angus and Hereford breeds. The breed difference in this study may have been enhanced by the lack of performance of the Hereford breed on the full grain ration used in the present study. Subjective evaluation of steers in each slaughter group indicated a general unthrifty condition of several of the Hereford steers (E. R. Lidvall, personal communication). Also a sick Hereford steer (112 days full feed) coupled with the above observation, contributed to the significant breed effect in the present study.

Data in Tables 9 and 10 generally outline similar trends discussed in Table 8. It is interesting to note, however, that the best three variable model of carcass measures for prediction of muscle to bone ratio was a measure of length or depth, a measure of muscling (width of l. dorsi) and a measure of fat (body-wall thickness). This is in agreement with Cole et al. (1964); Zinn et al. (1962) and Butterfield and Johnson (1971).

Data in Table 10 indicate that measures of fiber diameter or fiber area, percentage white fibers and fat cell diameter are the

Table 9. Coefficients of Determination for Multiple Regression Equations Predicting Muscle to Bone Ratio

Variables in Subset	Variables[a]	R^2 x 100	SEE[b]
	M:B-1		
3	2,3,7	58.38	.29
5	1,2,3,4,7	61.13	.21
9	Full Model	62.51	.29
3	2,6,7	51.28	.32
5	3,4,5,6,7	53.81	.32
7	All except 1,2	54.75	.32
	M:B-2		
3	2,3,7	60.00	.34
5	2,3,4,7,8	62.58	.34
9	Full Model	63.04	.37
3	3,6,7	53.09	.37
5	3,4,6,7,8	55.07	.37
7	All except 1,2	56.02	.37
	M:B-3		
3	2,6,8	56.09	.26
5	1,2,4,6,8	58.21	.26
9	Full Model	58.70	.27
3	4,6,8	45.39	.29
5	3,4,5,6,8	86.63	.28
7	All except 1,2	47.42	.30
	M:B-4		
3	2,4,8	56.63	.44
5	2,4,5,6,8	58.48	.42
9	Full Model	58.87	.44
3	4,6,8	42.04	.50
5	4,5,6,7,8	44.43	.51
7	All except 1,2	44.92	.52
	M:B-5		
3	2,4,8	61.26	.25
5	2,4,6,8	63.33	.24
9	Full Model	64.43	.25
3	4,6,8	50.18	.29
5	4,6,7,8,9	52.42	.28
7	All except 1,2	52.70	.30

Table 9 (continued)

Note: Regression equations above the line were calculated with fixed effects. Regression equations below the line were calculated without fixed effects.

[a]Variable code for fixed effects and certain carcass measurements:

1 = days on feed
2 = breed
3 = carcass length
4 = thorax depth
5 = length of L. dorsi
6 = width of L. dorsi
7 = body wall thickness (5.2 cm)
8 = Body wall thickness (10.4 cm)
9 = Body wall thickress (15.6 cm)

[b]SEE = standard estimate of error.

Table 10. Coefficients of Determination for Multiple Regression Equations Predicting Certain Muscle to Bone Ratios for Beef Varying in Time on Feed

Variables in Subset	Variables[a]	R^2 x 100	SEE
	Certain Chemical and Histological Measures		
	M:B-1		
3	1,2,6	48.66	.34
5	1,2,3,6,11	51.62	.34
11	Full Model	52.65	.35
3	3,6,9	32.77	.39
5	3,6,8,9,10	37.73	.39
9	All except 1,2	38.48	.40
	M:B-2		
3	1,2,6	49.55	.39
5	1,2,3,5,11	54.22	.39
11	Full Model	55.07	.41
3	3,5,9	32.56	.45
5	3,5,8,9,11	38.08	.45
9	All except 1,2	39.01	.47
	M:B-3		
3	1,2,10	51.33	.27
5	1,2,7,8,9	56.45	.26
11	Full Model	62.39	.26
3	7,9,10	27.00	.34
5	4,7,8,9,10	31.31	.33
9	All except 1,2	31.73	.32
	M:B-4		
3	1,2,10	48.64	.49
5	1,2,7,8,9	55.35	.46
11	Full Model	61.01	.46
3	4,7,8	24.45	.59
5	4,7,8,9,10	31.63	.56
9	All except 1,2	32.86	.59
	M:B-5		
3	1,2,10	54.85	.27
5	1,2,7,8,9	59.17	.26
11	Full Model	64.02	.27
3	4,7,9	29.10	.345
5	4,7,8,9,10	37.45	.33
9	All except 1,2	37.91	.33

Table 10 (continued)

Note: Regression equations above the line were calculated with fixed effects. Regression equations below the line were calculated without fixed effects.

[a]Variable code for fixed effects and certain chemical and histological measures:

1 = days on feed
2 = breed
3 = percentage moisture
5 = percentage fat (MFB)
6 = fiber diameter
7 = percentage white fibers
8 = percentage red fibers
9 = fat cell diameter
10 = histological marbling
11 = sarcomere length

[b]SEE = standard estimate of error.

best histological predictors of muscle to bone. This is in general agreement with West (1974).

Coefficients of determination and partial coefficients of determination predicting measures of muscle to bone ratio using a combination of fixed effects, carcass traits and histological traits are presented in Table 11. Regression equations combining selected fixed effects (by previous regression analysis), carcass and histological traits could account for an average of 57.09% of the variation in the muscle to bone ratio measures (Table 11). Coefficients of determination ranged from 43.49 to 49.44 (fixed effects), 33.96 to 41.56 (carcass traits) and 16.05 to 26.41 (histological) for muscle to bone measured in this study. An increase of 11.73% of the explained variation in muscle to bone measures was attained with the addition of carcass and histological traits to fixed effects. These data indicate that fixed effects (days on feed and breed) are superior to conventional carcass measures of composition and histological traits in predicting muscle to bone ratio for the 60 serial slaughtered steers used in the present study.

Partial coefficients of determination (PCD) partitioning variation in muscle to bone ratio measured by carcass and histological traits not previously explained by fixed effects ranged from 9.07 to 14.79%. These values are lower than PCD for fixed effects not previously accounted for by carcass traits and histological measures (15.11 to 20.77%). Although a combination of certain carcass traits and/or certain histological measures accounted for a reasonable percentage of the observed variation in muscling (Table 11), it

Table 11. Coefficients of Determination (CD) and Partial Coefficients of Determination (PCD) Predicting Various Muscle to Bone Ratios with Certain Fixed Effects of Carcass Traits and Histological Measures

Model	Kind of Model	M:B-1	M:B-2	M:B-3	M:B-4	M:B-5
Days and Breed, Carcass, Histological[a]	CD	52.93	56.88	57.65	57.19	60.79
Days and Breed	CD	44.03	43.49	45.57	44.29	49.44
Carcass	CD	33.96	39.43	35.55	34.45	41.56
Histological	CD	25.21	26.41	18.60	16.05	22.42
Carcass, Histological/Days, Breed[b]	PCD	9.07	14.94	13.98	14.77	13.44
Days and Breed/Carcass, Histological[c]	PCD	15.78	15.11	19.47	20.77	17.75
Days and Breed/Carcass[d]	PCD	14.37	12.44	16.56	18.51	16.03
Days and Breed/Histological[e]	PCD	23.66	23.78	34.59	34.76	31.81

[a]Full model includes: carcass (rib-size area, fat thickness and carcass weight), and histological (fiber diameter, percentage white fibers and fat cell diameter).

[b]Partial coefficients of determination accounting for variation in muscle to bone ratio which was not previous explained by days on feed and breed.

[c]Partial coefficients of determination accounting for variation in muscle to bone ratio which was not previously explained by carcass and histological traits.

[d]Partial coefficients of determination accounting for variation in muscle to bone ratio which was not previous explained by carcass traits.

[e]Partial coefficients of determination accounting for variation in muscle to bone ratio which was not previously explained by histological traits.

appeared that a knowledge of days on feed and/or breed contributes sufficient information to equations predicting muscling for serial slaughtered steers to justify further study.

CHAPTER V

CONCLUSIONS

Conclusions from a study of the effects of time on feed, carcass traits and histological measures on carcass muscling of 60 serial slaughtered Angus and Hereford steers are as follows: (1) five measures of muscle to bone ratio were linearly related ($P<.01$) to time on feed; (2) that the predicted values of M:B-1 at 140 days were near the maximum usually observed for muscle to bone ratio for these types of cattle; (3) among five objective measures of muscle to bone ratio, M:B-3 (BF to femur) and/or M:B-5 (BF + SM + AD to tibia) provided acceptable objective index for carcass muscling when dissection time and accuracy were simultaneously considered; (4) certain carcass traits (weight, adjusted fat thickness and rib-eye area) and histological measures (percentage white fibers, fiber diameter and fat cell diameter) were significantly related to all measures of muscle to bone ratio and to time on feed; (5) an eight variable multiple regression model consisting of two fixed effects, three carcass traits and three histological measures accounted for approximately 61% of the observed variation in M:B-5; (6) fixed effects (breed and time on feed) carcass traits and histological measures accounted for approximately 49, 42, and 22% of the observed variation in M:B-5, respectively; and (7) for a population sample of serial slaughtered steers, fixed effects (time on feed and breed) explained 16 and 31.8% of the variation in M:B-5 not previously accounted for by carcass traits and histological measures, respectively.

PART II

THE EFFECTS OF DAYS ON FEED, CARCASS TRAITS AND HISTOLOGICAL MEASURES ON TENDERNESS AND FLAVOR OF FORAGE AND GRAIN FED BEEF

CHAPTER I

INTRODUCTION

The profit margin for beef production has declined in recent years. This is partially due to high feed costs, rising land prices and reduced availability of land for cereal crop production. The stress caused by these factors has stimulated interest in development of alternative systems of feed management. Finishing cattle on forage or reduced days on feed is a logical option which is being widely investigated by researchers in the Southwestern and Southeastern regions of the United States. Forage and limited-grain finished cattle are lower in quality and palatability when compared to full grain finished beef (Kropf et al., 1975; Cross and Dinius, 1978; and Schroder et al., 1980). Dryden et al. (1973) and Dinius and Cross (1978) have reported fatty acid composition to be related to sensory juiciness and flavor. Researchers, however, have not fully explained the physical, chemical and histological changes which occur during transformation of cattle from forage to grain finished beef; nor have they determined the minimum days on feed for a specific steer (varying in frame score or breed) required to optimize carcass composition and eating quality. Consequently this study was designed: (1) to determine the effects of time on feed, carcass traits and histological measures on sensory flavor and tenderness and (2) to determine the time on feed to optimize flavor and tenderness of grain fed steers.

CHAPTER II

REVIEW OF LITERATURE

Bidner (1975) concluded that forage-finished cattle gained slower, had a yellow tinted fat and were lower in final weight, quality grade, dressing percentage and acceptable palatability attributes unless fed to comparable weights and grades as grain-finished beef. These findings are in general agreement with variations in certain traits between forage- and grain-finished beef reported by other researchers: tenderness (Meyer et al., 1960; Chapman et al., 1971; Lusby, 1977; Bowling et al., 1978); flavor (Meyer et al., 1960; Reddish, 1956; Altzin et al., 1971; Purchas and Davies, 1974; Bowling et al., 1976; Kropf et al., 1975; Bowling et al., 1978; and Brown et al., 1979); lean and fat color (Kropf et al., 1975; Schroder et al., 1980; Harrison et al., 1972); quality grade (Meyer et al., 1960; Cross and Dinius, 1978; Dinius and Cross, 1978); and dressing percentage (Dinius and Cross, 1978; Harrison et al., 1978; and Schroder et al., 1980).

Bowling et al. (1978) reported lower scores for tenderness rating for forage-finished beef. He stated that an increase in fat thickness below 7 to 9 mm was correlated with an increased tenderness score, and concluded that toughening effects may be due to cold shortening for cattle with inadequate marbling and fat cover. This is in agreement with earlier work (Bowling et al., 1977) which indicated an association existed between increased fat thickness and sarcomere length. Kropf et al. (1975) and Bowling et al. (1976) reported lower Warner-Bratzler shear force values (SFV) for grain-finished than

forage-fed beef. These data are in disagreement with Harrison et al. (1978) who reported no difference in SFV between cattle on different nutritional feeding regimens. Huffman (1974) reported that forage-finished beef was slightly more tender than grain-finished. Bayne et al. (1969) found no difference between cattle fed a low energy corn silage or a high energy corn ration.

Researchers (Purchas and Davies, 1974, and Bowling et al., 1976) indicate that sensory evaluation panels in this country assign lower flavor and overall desirability scores to forage-finished beef. Wanderstock and Miller (1948) indicated that annual and seasonal factors can vary the quality of grass and forage diets, which can alter the cooked steak flavor of beef. Malphrus (1957) reported flavor differences between steaks with yellow fat compared to white fat. Moody (1976) stated that flavor was highly associated with percentage intramuscular fat of the l. dorsi. Marchello et al. (1968) reported marbling was correlated with chemical fat of the l. dorsi, although large differences were found in other muscles studied. Edwards et al. (1961) reported that addition of beef tallow to grain and/or forage rations significantly changes the fatty acid composition of steers. They found that the concentration of C18:0 was higher and C14:0 was lower in steers fed grain plus fat (dry lot) than steers fed grain plus fat (pasture). Church et al. (1967) reported differences in fatty-acid composition between wheat and barley fed animals. They found wheat finished beef contained higher amounts of C14:0, C16:0 and C16:1 and less C18:0 than animals finished on barley. Dryden et al. (1969, 1970, 1973) reported an increase in unsaturated fatty acids (especially oleic acid) with days on feed, whereas the level of

linoleic and lactic acid was negatively correlated with flavor and juiciness ratings. Dinius and Cross (1978) reported that grain fed steers increased in oleic acid and decreased in stearic acid level while on short periods (5 weeks) of concentrated feed. Ferrell et al. (1968) reported sex differences in fatty acid composition, although individual fatty acids were not significantly correlated with organoleptic scores. Skelly et al. (1978) reported no difference in fatty acid composition between animals studied, although flavor differences were noted by the sensory evaluation panel. Brown et al. (1979) reported that ground beef from forage-finished steers differed in fatty acid composition from both grain-finished and limited grain-finished steers, indicating that fatty acid composition changes with type of diet.

CHAPTER III

EXPERIMENTAL PROCEDURE

Procedures for the basic design carcass evaluation and statistical analysis are outlined in Chapter III of Part I, page 7.

Sample Preparation

The short loin was faced at the 13th rib to remove dessicated tissues and subsequently segmented into six steaks for the following analyses: proximate analysis and sarcomere length (1.3 cm); fragmentation index (0.6 cm); Warner-Bratzler shear (2.5 cm); sensory evaluation (2.5 cm); sensory training (2.5 cm); and, total lipid analysis (1.3 cm).

Cookery

Warner-Bratzler shear force steaks and sensory evaluation steaks were each wrapped in polyethylene coated freezer paper, frozen and stored at -30 C. They were thawed for 24 hours in a 5 to 7 C cooler prior to cooking. Each steak was broiled to an internal temperature of 70 C (monitored by a YSI Telethermometer thermo-couple device) on a preheated "Farberware" broiling unit at approximately 250 C. Degree of doneness was scored using an 8-point scale (8=very well done, 1=rare), cooking time and cooking loss were also recorded for each steak. Steaks were wrapped in aluminum foil to insure warm samples for panelists. Warner-Bratzler shear steaks were allowed to cool to 25 C. Four (2.5 x 1.3 cm i.d.) cores were removed and sheared in duplicate (total of eight shear measurements per steak) on a Warner-Bratzler shear force machine. Palatability steaks were weighed, boned and cut into 1.3 x 1.3 x 1.9 cm cubes. Cubes were

randomly selected and served hot to each of a 10-member trained sensory evaluation panel (Cross et al., 1972). Panelists independently rated each sample and assigned scores on an 8-point descriptive scale for juiciness, tenderness and flavor intensity; and flavor desirability and overall desirability using an 8-point hedonic scale (8=extremely juicy, extremely tender, extremely intense beef flavor and extremely desirable; 1=extremely dry, extremely tough, extremely intense milky flavor and extremely undesirable, respectively).

Round steaks (semimembranosus muscle) were also evaluated by a sensory panel and a Warner-Bratzler shear force machine as outlined above.

Fragmentation Index

Fragmentation index was determined according to the Davis et al. (1980a) procedure. However, the dorsal blade was set 1 mm below the solution surface according to Calkins and Davis (1978).

Lipid Extraction and Evaluation

Total lipid analysis was conducted on l. dorsi muscle for type and percentage of fatty acids (C-14 through C-20). Extraction was performed using the method of Melton et al. (1979). Fatty acids of total lipids were determined by gas liquid chromatography of fatty acids methyl esters according to procedures outlined in AOCS (1971).

Sarcomere Length

Sarcomere length was determined on l. dorsi muscle (cooler aged 240 hours), blended in an Osterizer cycle-blend for two min with 25 ml of a 4% formalin solution. A light microscope equipped with a filar

micrometer (magnification = 1500x) was used to measure five sarcomeres on each of 24 myofibrils.

Histological Measures

Experimental procedures for determination of fiber type, fiber diameter, fiber area, fat cell diameter and histological marbling score are outlined in Appendix Table 1. These histological determinations were conducted by Robert E. Sutton, Jr. (a Master of Science student under the direction of Dr. C. C. Melton, Food Technology and Science Department, The University of Tennessee, Knoxville). Since these measures were conducted on muscle tissue from all carcasses included in the present study, and since these measures have been shown to be related to muscling or palatability traits, permission was granted from Sutton and Melton to incorporate these data into this M.S. thesis.

Proximate Analysis

Proximate analysis samples (Steak A) were trimmed of all epimyseal tissue, cubed and frozen in liquid nitrogen and powdered in a Waring blender. Percentage moisture was determined at 100 C using a vacuum oven. Samples were dried 8 to 12 hours and the fat extracted with anhydrous ether in a soxhlet fat extraction apparatus. Percentage fat was computed for both whole tissue basis (WTB) and moisture free basis (MFB). AOAC (1975) procedures were followed.

Statistical Analysis

See Section I, page 11.

CHAPTER IV

RESULTS AND DISCUSSION

Mean values for carcass quality traits are presented in Table 12. Marbling degree, quality grade, lean color and lean firmness all increased ($P<.01$) linearly across time on feed. This is in agreement with Zinn et al. (1961) and Dinius and Cross (1978). Sarcomere length, fiber diameter, fiber area and percentage fat (MFB) also increased ($P<.01$) across days on feed (Table 13). The increase in sarcomere length may have been the result of cold shortening which occurs with muscle covered with a limited degree of subcutaneous fat. This is in agreement with Smith et al. (1976).

Data presented in Tables 14 and 15 are means and simple correlation coefficients for palatability attributes of loin steaks. These data indicate that flavor, juiciness and tenderness rating increased linearly ($P<.01$) with time on feed. This is in general agreement with Reddish (1956), Mayer et al. (1960), Oltjin et al. (1971) and Kropf et al. (1975).

Flavor and tenderness rating were highly correlated ($P<.01$) with time on feed, marbling degree, lean color, carcass weight, adjusted fat thickness, body wall thickness, fat cell diameter and percentage fat.

A reduction in the sum of squares (not shown in tabular form) for time on feed was observed, with addition of physical, chemical or histological measures. Thus these measures used to predict sensory flavor and tenderness of the loin are directly related to time on feed. This is in general agreement with Zinn et al. (1961), Cross and Dinius (1978) and Bowling et al. (1977).

Table 12. Mean Values for Quality Indicators

	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
				Marbling Degree[c]					
Angus	12.5	3.6	28.7	8.4	11.6	11.0	12.8	14.2	17.0
Hereford	10.6	3.4	31.9	7.0	9.4	10.4	9.2	12.2	15.4
All*	11.6	3.6	81.1	7.7	10.5	10.7	10.9	13.2	16.2
				US Quality Grade[d]					
All*	10.2	2.1	20.6	7.7	9.6	10.2	10.1	11.6	12.7
				Marbling Texture[e]					
All*	5.5	1.4	25.1	---	5.7	5.8	5.2	5.3	5.4
				Marbling Variability[e]					
All*	5.0	2.1	42.3	---	5.7	4.9	3.2	5.4	5.6
				Marbling Distribution[e]					
All*	6.0	1.5	24.5	---	6.6	6.2	5.3	5.6	6.4
				Lean Color[f]					
All*	5.1	1.4	26.9	4.5	4.5	5.5	4.5	5.6	5.8
				Lean Texture[f]					
All*	4.9	1.5	33.4	4.0	5.0	4.3	3.3	5.5	5.2
				Lean Firmness[f]					
All*	5.9	1.5	24.6	5.3	5.5	6.0	6.4	6.6	5.8
				Overall Maturity[k]					
All*	16.5	1.62	10.1	15.4	15.4	15.7	17.0	16.2	16.6

Table 12 (continued)

[a]SD = standard deviation

[b]CV = coefficient of variation

[c]Marbling degree = 30 unit scale: 30 = AB^{+}, 1 = D^{-}.

[d]Quality grade = 17 unit scale: 6 = STD^{-}, 17 = P^{+}.

[e]8 = very fine, very uniform, very uniform size; 1 = very coarse, very uneven, extremely variable size, for marbling texture, marbling variability and marbling distribution, respectively.

[f]8 = light grayish red (pink), very firm, very fine; 1 = black, very soft, very coarse, for lean color, lean firmness and lean texture, respectively.

[k]Overall maturity = A^{00} = 10, A^{50} = 15, A^{100} = 20.

Table 13. Mean Values of Certain Physical, Chemical and Histological Measures of the l. dorsi from Beef Stratified According to Days on Feed

Trait	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
FI (loin)[c]	4.77	1.1	23.2	6.09	4.57	4.83	4.73	4.29	4.13
Armor tenderometer[d]	16.4	3.9	24.0	20.50	-	10.80	17.00	15.70	19.00
Sarcomere length (μm)	2.1	0.2	7.9	2.00	2.10	2.30	2.00	2.20	2.20
Fiber diameter	50.8	7.1	14.0	52.30	45.70	43.70	51.80	57.00	54.30
Fiber area	2.1	0.6	27.7	2.20	1.70	1.50	2.10	2.60	2.40
Percentage moisture (WTB)[e]	72.7	1.6	2.2	73.10	72.80	72.50	73.00	72.20	72.60
Fat (%, WTB)	3.9	1.4	35.8	3.30	3.60	3.50	3.60	4.00	5.30
Fat (%, MFB)[f]	14.0	4.7	33.8	11.80	13.00	12.60	13.00	14.30	19.00

[a]SD = standard deviation.

[b]CV = coefficient of variation.

[c]FI (loin) = fragmentation index of the loin.

[d]Missing values for 0 days (N = 2); 28 days (N = 10).

[e]WTB = whole tissue basis.

[f]MFB = moisture-free basis.

Table 14. Simple Correlation Coefficients Relating Sensory Evaluation Attributes to Certain Physical, Chemical and Histological Traits

Trait	Sensory Evaluation Variables for Loin Steaks				
	Flavor Rating	Juiciness Rating	Tenderness Rating	Flavor Desirability	Overall Desirability
Days on feed	.67**	.36**	.36**	.63**	.59**
Marbling degree	.58**	.21	.37**	.57**	.50**
Lean texture	.14	.11	.07	.14	.08
Lean color	.32**	.17	.32**	.34**	.33**
Overall maturity	.18	.31**	.04	.16	.18
Carcass weight	.70**	.31**	.30**	.68**	.54**
Adjusted fat thickness	.51**	.23	.29*	.48**	.42**
Percentage KPH	.53**	.21	.24	.53**	.41**
Body-wall thickness	.68**	.29*	.38**	.68**	.58**
Rib-eye area	.60**	.26*	.32**	.57**	.50**
Yield grade	.52**	.26*	.23	.51**	.40**
Fiber diameter	.31*	.24	.10	.34**	.28*
Fiber area	.31**	.25*	.12	.34**	.30*
Percentage red fibers	.37**	.05	.20	.37**	.30*
Percentage white fibers	.39**	.02	.16	.39**	.29*
Fat cell diameter	.53**	.32**	.32**	.50**	.47**
Sarcomere length	.11	.13	.38**	.11	.24

Table 14 (continued)

Trait	Sensory Evaluation Variables for Loin Steaks				
	Flavor Rating	Juiciness Rating	Tenderness Rating	Flavor Desirability	Overall Desirability
Percentage moisture (WTB)	.19	.06	.09	.24	.16
Percentage fat (MFB)	.49**	.34**	.28*	.57**	.46**

*(P<0.05).

**(P<0.01).

Table 15. Mean Values for Certain Palatability Attributes and Warner-Bratzler Shear Values for Loin Steaks from Beef Slaughtered at Six Different Times on Feed

Palatability Attribute	Overall			Days on Feed					
	Mean	DS[a]	CV[b]	0	28	56	84	112	140
Flavor rating[c]	5.1	0.8	16.0	4.3	4.5	5.1	5.2	5.7	5.8
Juiciness rating[c]	5.6	0.7	13.3	5.2	5.0	5.6	5.8	5.8	5.8
Tenderness rating[c]	5.2	1.1	21.7	4.2	5.1	5.4	5.2	5.5	5.7
Warner-Bratzler shear force (Kg)	3.6	0.9	25.4	4.0	3.8	3.8	3.7	3.1	3.0
Flavor desirability rating[c]	5.0	0.9	17.8	4.3	4.3	5.0	5.0	5.7	5.8
Overall desirability rating[c]	5.0	0.9	18.3	4.2	4.5	5.1	5.1	5.6	5.7
Degree of doneness	2.8	0.7	23.5	2.9	2.7	2.7	3.0	2.7	2.6
Cooking loss (%)	24.2	0.6	24.9	26.3	26.2	22.4	20.3	23.7	26.2

[a]DS = standard deviation.

[b]CV = coefficient of variation.

[c]8 = extremely intense beef flavor, extremely juicy, extremely tender, extremely desirable; 1 = extremely intense milky flavor, extremely dry, extremely tough, extremely undesirable, for flavor, juiciness, tenderness, flavor desirability and overall desirability, respectively.

Simple correlation coefficients and mean values for sensory evaluation of semimembranous steaks are presented in Tables 16 and 17. Among the three principle palatability attributes only flavor rating increased with days on feed ($P<.05$). Days-on-feed, carcass weight, fiber diameter, fiber area, and percentage fat were correlated ($P<.05$) with flavor. Flavor desirability was correlated significantly with percentage fat, carcass weight, rib-eye area and body wall thickness while overall desirability was correlated with marbling degree ($P<.01$) and body wall thickness ($P<.05$). Tenderness and juiciness of the semimembranous steaks were not significantly related with various physical, chemical and histological measures (Table 16). This may be a result of the limited variation in tenderness and juiciness of the inside round steaks across time on feed, since time on feed contributed major proportions of variation found in the variables used to predict palatability attributes in the present study.

Coefficients of determination for multiple regression equations predicting sensory tenderness and Warner-Bratzler shear force value of loin steaks are presented in Table 18. These data indicate that days on feed, carcass traits (carcass weight, adjusted fat thickness, marbling degree, lean color and l. dorsi area), histological measures (percentage white fibers, fiber diameter and fat cell diameter) and fragmentation index accounted for 42.53 and 26.30% of the observed variation in sensory tenderness and Warner-Bratzler shear, respectively. Among all physical, chemical and histological measures studied, FI accounted for the greatest percentage (30:3%) of observed variation in sensory tenderness. This is in agreement with Calkins et al. (1980).

Table 16. Simple Correlation Coefficients Relating Sensory Evaluation Variables to Certain Physical, Chemical and Histological Traits

	Sensory Evaluation Variables for Semimembranous Steaks				
	Flavor Rating	Juiciness Flavor	Tenderness Rating	Flavor Desirability	Overall Desirability
Days on Feed	.30*	.19	.10	.24	.22
Marbling Degree	.22	.08	.21	.22	.33**
Lean Texture	.04	-.01	-.01	.01	-.02
Lean Color	.20	-.27*	-.20	.21	.00
Overall Maturity	.08	.07	-.19	.00	.02
Carcass Weight	.28*	.01	-.04	.26*	.23
Adjusted Fat Thickness	.15	-.03	.00	.12	.10
Percentage KPH	.18	.13	.04	.15	.23
Body Wall Thickness	.37**	.07	.03	.35**	.26*
Rib Eye Area	.29*	-.11	-.02	.25**	.18
U.S. Yield Grade	.07	.07	-.05	.03	.04
Fiber Diameter	.31**	-.01	-.23	.24	.09
Fiber Area	.28*	-.03	-.23	.22	.06
Percentage, Red Fibers	-.16	.04	-.02	-.10	-.06
Percentage, White Fibers	.16	-.02	.02	.11	.07
Fat Cell Diameter	.23	.08	-.10	.28	.05
Sarcomere Length	-.16	-.27*	-.16	-.12	-.23
Percentage Moisture (WTB)	.02	.16	-.07	.05	-.03
Percentage Fat (MFB)	.35**	-.14	-.05	.35**	.23

*P < 0.05

**P < 0.01

Table 17. Mean Values for Certain Palatability Attributes and Warner-Bratzler Shear Values for *Semimembranosus* Steaks

Palatability Attributes	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
Flavor rating[c]	4.35	0.7	16.2	4.4	4.1	3.8	4.4	4.5	4.8
Juiciness rating[c]	5.01	0.7	14.5	4.6	5.0	4.9	5.3	5.1	5.1
Tenderness rating[c]	3.72	0.7	17.9	3.5	4.0	3.5	3.6	3.8	3.9
Warner-Bratzler shear force (Kg)	4.42	0.8	17.3	4.34	4.23	4.54	4.93	4.46	4.06
Flavor desirability rating[c]	3.84	0.7	18.2	3.9	3.7	3.4	3.8	4.0	4.1
Overall desirability rating[c]	3.78	0.5	13.7	3.7	3.9	3.4	3.7	3.9	4.1
Degree of doneness	2.7	0.8	27.9	2.8	2.7	2.7	2.8	2.6	2.7
Cooking loss (%)	29.1	1.2	42.7	29.3	30.3	22.1	29.5	32.4	32.7

[a]SD = standard deviation.

[b]CV = coefficient of variation.

[c]8 = extremely intense beef flavor, extremely juicy, extremely tender, extremely desirable; 1 = extremely intense milky flavor, extremely dry, extremely tough, extremely undesirable, for flavor, juiciness, tenderness, flavor desirability and overall desirability, respectively.

Table 18. Coefficients of Determination for Multiple Regression Equation Predicting Sensory Tenderness and Warner-Bratzler Shear of Loin Steaks from Beef Varying in Time on Feed Using Fixed Effects, Carcass Traits, Histological Measures and Fragmentation Index

Variables in Subset	Variables[a]	R^2 x 100	SEE[b]
1	1	12.68	1.06
1	10	30.27	0.92
3	4,5,10	38.95	0.88
6	3,4,5,6,9,10	41.48	0.88
10	Full Model	42.53	0.92
9	All except (1)	42.50	0.90
8	All except (1,10)	30.69	0.99
5	All carcass	18.50	1.06
3	All histological	12.20	1.05
1	1		
1	9	19.43	1.80
3	6,9,10	24.23	1.80
6	2,4,5,9,10	26.06	1.83
10	Full Model	26.30	1.89
9	All except (1)	26.30	1.89
8	All except (1,10)	22.91	1.89
5	All carcass	13.11	1.95
3	All histological	20.22	1.85

[a]Variable code for fixed effects, carcass traits, histological measures and fragmentation index:

1 = days on feed (fixed effects)
2 = carcass weight (carcass)
3 = adjusted fat thickness (carcass)
4 = marbling degree (carcass)
5 = lean color (carcass)
6 = *l. dorsi* area (carcass)
7 = percentage white fibers (histological)
8 = fiber diameter (histological)
9 = fat cell diameter (histological)
10 = fragmentation index

[b]SEE = standard estimate of error.

Coefficients of determination for prediction of tenderness rating were 12.68 (days on feed), and 30.27 (fragmentation index) (Table 19).

Little increase (.03%) was obtained with the addition of days on feed to carcass traits and histological measures, while the addition of both fixed effects and fragmentation index increased the percentage of explained variation by 11.85%. These data indicate that fragmentation index is only slightly affected by days on feed and can explain variation in beef tenderness other than that caused by degree of finish or days on feed for serially slaughtered grain-fed steers.

Regression analyses indicate that the best three variables for prediction of shear force value (l. dorsi area, fat cell diameter and fragmentation index) accounted for 24.23% of the observed variation (Table 19). The addition of fixed effects, four carcass traits and one histological measure (full model) increased the percentage by 2.07%. This indicates that the optimum model consists of three variables for prediction of shear force value.

Partial coefficients of determination partitioning variation in sensory tenderness were 8.53 (carcass/days on feed, histological and FI), and 11.85 (FI/days on feed, carcass and histological). These data indicated that although a combination of certain carcass traits, fixed effects and/or histological measures accounted for a reasonable percentage of the observed variation in tenderness, it appears that fragmentation index contributes sufficient information to equations predicting tenderness to justify its use as a measure of tenderness of serially slaughtered beef.

Table 19. Coefficients of Determination (CD) and Partial Coefficients of Determination (PCD) Predicting Sensory Tenderness of Loin Steaks with Measurements of Fixed Effects, Carcass Traits, Histological Measures and Fragmentation Index (FI)

Model	Kind of Model	Tenderness
Days on feed, Carcass, Histological, FI[a]	CD	42.53
Days on feed	CD	12.68
Carcass	CD	18.50
Histological	CD	12.20
FI	CD	30.27
Days on feed/Carcass, Histological, FI[b]	PCD	0.03
Carcass/Days on feed, Histological, FI[c]	PCD	8.53
Histological/Days on feed, Carcass, FI[d]	PCD	0.80
FI/Days on feed, Carcass, Histological[e]	PCD	11.85

[a]Full Model includes: Carcass (carcass weight, adjusted fat thickness, marbling degree, lean color and l. dorsi area) and histological (percentage white fibers, fiber diameter and fat cell diameter).

[b]Partial coefficients of determination accounting for variation in tenderness which was not previously explained by carcass traits, histological measures and FI.

Table 19 (continued)

[c]Partial coefficients of determination accounting for variation in tenderness which was not previously explained by days on feed, histological measures and FI.

[d]Partial coefficients of determination accounting for variation in tenderness which was not previously explained by days on feed, carcass traits and FI.

[e]Partial coefficients of determination accounting for variation in tenderness which was not previously explained by days on feed, carcass and histological measures.

Data presented in Table 20 are mean values for fatty acid percentage in the L. dorsi muscle. These data indicate that fatty acids C14:0, C17:0, C16:1, and C18:1 increased while C18:0 and C18:3 decreased linearly ($P<.01$) across time on feed.

Coefficients of determination (CD) for regression equations predicting sensory flavor of loin steaks are presented in Table 21. The CD's for flavor were 44.70 (fixed effects), 36.28 (carcass traits) 46.75 (chemical measures), 48.06 (fixed effects plus carcass traits) and 55.93 (chemical measures plus fixed effects). These data indicate that carcass traits (adjusted fat thickness, marbling degree and lean color) and chemical measures (fatty acid percentages C14:0, C17:0, C16:1, C18:1, C18:2 and C18:3) were directly related ($P<.01$) to days on feed. The addition of fixed effects to carcass or chemical measures increased the percentage of variation explained in flavor by 11.78 and 9.18%, respectively. A combination of the best predictors of beef flavor as determined by previous regression analyses indicate that time on feed and C18:2 was the best two-variable model explaining 49:03% of the observed variation. Addition of two carcass traits, two histological measures and two chemical measures increase the amount of explained variation in flavor by 2.25%. These data indicate that measures used to predict flavor are multicolinear with days on feed.

Partial coefficients of determination (PCD) partitioning variation in beef flavor of serial slaughtered steers (Table 22) indicate that all groups of variables (days, carcass, histological, chemical) used to predict flavor were approximately equal in effectiveness in prediction of sensory flavor rating. Partial coefficients

Table 20. Mean Values for Fatty Acid Percentage in l. dorsi Muscle

Fatty Acids[a]	Overall			Days on Feed					
	Mean	SD[b]	CV[c]	0	28	56	84	112	140
C14:0	2.84	0.4	14.7	1.43	2.65	3.01	2.85	2.98	3.14
C16:0	26.29	1.3	5.0	25.67	26.42	25.88	26.16	26.37	27.26
C16:1	4.16	0.6	13.3	3.85	3.84	4.13	4.17	4.45	4.54
C17:0	2.16	0.6	27.0	1.54	2.17	2.32	2.31	2.35	2.28
C18:0	14.26	3.3	23.1	20.09	14.74	14.05	13.00	12.08	11.59
C18:1	42.47	2.9	6.7	38.26	41.95	42.74	43.37	44.11	44.36
C18:2	4.50	0.8	17.6	4.30	4.68	4.36	4.98	4.47	4.22
C18:3	0.95	0.5	55.8	1.34	1.22	1.07	0.78	0.75	0.59
				97.48	97.67	97.56	97.56	97.56	97.98

[a]2.0 to 2.5% of the fatty acids were not identified and are not presented.

[b]SD = standard deviation.

[c]CV = coefficient of variation.

Table 21. Coefficients of Determination for Regression Equation Predicting Sensory Flavor of Loin Steaks from Beef Varying in Time on Feed

Variables in Subset	Variables[a]	R^2 x 100	SEE[b]
	Carcass Traits		
1	1	44.70	.61
2	1,3	47.08	.60
3	1,3,4	47.68	.60
3	All carcass	36.28	.67
4	All carcass + fixed effects	48.06	.61
	Chemical		
2	1,13	49.03	.59
3	1,10,13	53.79	.62
4	1,10,11,13	54.82	.63
7	All fatty acid	46.53	.63
8	All fatty acid	46.53	.63
9	Fatty acid + feed effects	55.84	.63
	Combined Fixxed Effects, Carcass[c] Traits, Histological and Chemical Measures		
2	1,13	49.03	.59
3	1,5,13	50.21	.59
5	1,4,5,11,13	50.99	.60
8	Full Model	51.28	.62

[a]Variable code for fixed effects, carcass traits, histological measures and chemical measures:

1 = days on feed (fixed effects)
2 = adjusted for thickness (carcass)
3 = marbling degree (carcass)
4 = lean color (carcass)
5 = percentage white fibers (histological)
6 = fat cell diameter (histological)
7 = C14:0 (chemical)
8 = C17:0 (chemical)
9 = C16:1 (chemical)

Table 21 (continued)

10 = C18:0 (chemical)
11 = C18:1 (chemical)
12 = C18:2 (chemical)
13 = C18:3 (chemical)

[b]SEE = standard estimate of error.

[c]Combined variables = 1,3,4,5,6,-1,12,13.

Table 22. Coefficients of Determination (CD) and Partial Coefficients of Determination (PCD) Predicting Sensory Flavor of Loin Steaks with Measurements of Fixed Effects, Carcass Traits, Histological Measures and Chemical Measures

Model	Kind of Model	R^2 x 100
Days on feed, Carcass, Histological, Chemical[a]	CD	52.37
Days on feed	CD	45.29
Carcass	CD	36.28
Histological	CD	33.28
Chemical	CD	38.93
Days on feed/Carcass, Histological, Chemical[b]	PCD	5.26
Carcass/Days on feed Histological, Chemical[c]	PCD	1.34
Histological/Days on feed, Carcass, Chemical[d]	PCD	0.79
Chemical/Days on feed, Carcass, Histological[e]	PCD	2.20

[a]Full Model includes: Carcass (adjusted fat thickness, marbling degree, and lean color), histological (percentage white fibers and fat cell diameter), and chemical (C14:0, C17:0 and C18:3).

[b]Partial coefficients of determination accounting for variation in flavor which was not previously explained by carcass, histological and chemical measures.

[c]Partial coefficients of determination accounting for variation in flavor which was not previously explained by Days on feed, histological and chemical measures.

Table 22 (continued)

[d]Partial coefficient of determination accounting for variation in flavor which was not previously explained by Days on feed, carcass and chemical measures.

[e]Partial coefficient of determination accounting for variation in flavor which was not previously explained by Days on feed, carcass, and histological measures.

of determination for prediction of flavor rating for days on feed (not previously explained by chemical measures, carcass traits and histological measures) was 5.27%. This was higher than PCD for carcass (1.34%) chemical measures (2.20%) and histological measures (.79%) (Table 22). These data indicate that days on feed was the best predictor of beef flavor for serial slaughtered steers. It also appears that knowledge of chemical measures contribute sufficient information to prediction equations for flavor of serial slaughter beef to justify further study.

CHAPTER V

CONCLUSION

The conclusions of the present study are: (1) time on feed was related positively ($P<.01$) to sensory flavor and tenderness of loin steaks; (2) neigher breed or feeder calf classification were related to sensory flavor or tenderness; (3) time on feed was related to flavor rating of the semimembranosus muscle; (4) tenderness and juiciness of semimembranosus steaks were not related to any measures used in this study; (5) among all physical, chemical and histological measures studied, FI accounted for the greatest percentage of observed variation in sensory tenderness of loin steaks; (6) fragmentation index was slightly affected by time on feed, but was able to account for variation in sensory tenderness caused by variables other than days on feed or degree of finish; (7) C14:0, C17:0, C16:1 and C18:1 increased linearly ($P<.01$), whereas C18:0 and C18:3 decreased across time on feed; (8) 33.3 to 45.3% of the observed variation in flavor rating can be explained by the use of time on feed, carcass traits, histological or chemical measures; 52.3% can be accounted for from use of all measures combined.

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APPENDIX

Table A-1. Mean Values for Certain Measures of the Round

Trait	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
Round weight (kg)	28.4	5.0	17.7	23.3	24.9	27.2	27.3	32.9	34.6
Depth of round (cm)[c]	23.4	2.4	10.1	22.7	22.7	21.9	22.7	24.3	26.1
Width of round (cm)[d]	42.7	2.8	6.7	39.4	41.9	42.4	43.2	44.3	44.6
Cushion length (cm)[e]	39.1	3.8	10.0	34.8	37.6	39.1	38.5	43.3	41.4

[a]SD = standard deviation.

[b]CV = coefficient of variation.

[c]Depth of round = the distance from the aitch bone perpendicular to the outside round passing through the anterior end of the exposed femur.

[d]Width of round = width of the exposed lean (lateral edge of the tensor fasciae latae to lateral edge of biceps femoris.

[e]Cushion length = the posterior end of the cushion (at the femur-tibia joint) to the medial tip of the ischium in the exposed round face.

Table A-2. Mean Weight for Various Muscles of the Round

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
	Total Muscle Weight of the Round (kg)								
Angus	19.2	3.1	16.1	16.0	17.4	18.0	18.4	22.2	23.1
Hereford	18.3	3.1	16.9	15.3	16.3	18.3	17.6	20.6	21.8
All	18.8	3.1	16.6	15.7	16.9	18.2	18.0	21.4	22.4
	Biceps Femoris (kg)								
Angus	4.9	0.8	16.9	1.1	4.4	4.5	5.1	5.4	5.8
Hereford	4.7	0.9	18.5	3.9	4.2	4.7	4.3	5.2	5.6
All	4.8	0.8	17.7	4.0	4.3	4.6	4.7	5.3	5.7
	Semimembranosus (kg)								
Angus	3.4	0.6	16.5	2.9	3.1	3.2	3.5	4.0	3.9
Hereford	3.3	0.6	17.5	2.8	3.1	3.3	3.1	3.7	3.9
All	3.4	0.6	17.0	2.8	3.1	3.2	3.3	3.9	3.9
	Adductor (kg)								
Angus	1.2	0.2	14.4	1.1	1.1	1.2	1.2	1.3	1.4
Hereford	1.2	0.2	13.2	1.2	1.1	1.1	1.1	1.2	1.3
All	1.2	0.2	13.8	1.1	1.1	1.1	1.1	1.3	1.3

[a]SD = standard deviation.

[b]CV = coefficient of variation.

Table A-3. Mean Weights for Various Bones of the Round

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
	Total Bone Weight of Round (kg)[c]								
Angus	5.13	0.79	15.4	5.05	4.57	5.05	4.83	5.55	5.75
Hereford	5.39	0.71	13.1	4.95	5.48	5.13	5.07	5.67	6.06
All	5.26	0.75	14.3	5.00	5.03	5.09	4.95	5.61	5.90
	Femur Weight (kg)								
Angus	1.71	0.23	13.6	1.61	1.56	1.73	1.71	1.94	1.74
Hereford	1.86	0.24	13.0	1.66	1.85	1.84	1.85	1.92	2.05
All	1.78	0.25	13.8	1.64	1.71	1.78	1.78	1.93	1.90
	Tibia Weight (kg)								
Angus	1.08	0.16	14.6	1.02	0.98	1.12	1.05	1.14	1.16
Hereford	1.14	0.13	11.1	1.05	1.15	1.16	1.10	1.15	1.20
All	1.11	0.14	13.0	1.04	1.06	1.14	1.08	1.15	1.18

[a]SD = standard deviation.

[b]CV = coefficient of variation.

[c]Total bone weight of round = weight of all bones and major connective tissue in the round.

Table A-4. Mean Weights for Various Kinds of Fat in the Round

Trait	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
Outside fat[c]	0.78	0.31	40.4	0.66	0.67	0.80	0.66	0.78	0.70
Outside fat (excess)[d]	0.59	0.49	84.7	0.07	0.20	0.42	0.53	1.28	1.07
Inside fat[e]	0.62	0.28	45.5	0.46	0.57	0.56	0.60	0.56	0.98
Inside fat (excess)[f]	0.59	0.50	86.1	0.06	0.21	0.40	0.47	1.20	0.95
Seam fat[g]	0.83	0.40	48.3	0.70	0.66	0.95	0.91	0.65	1.12
Seam fat (excess)[h]	0.50	0.32	63.5	0.06	0.30	0.42	0.55	0.77	0.77
Total fat weight (kg)[i]	3.91	1.8	42.5	2.01	2.61	3.55	3.72	5.24	5.52
Seam fat total weight (kg)	1.33	0.6	42.4	0.76	0.96	1.37	1.46	1.42	1.89
Outside fat total weight (kg)	1.37	0.6	46.7	0.73	0.87	1.22	1.19	2.06	1.79
Inside fat total weight (kg)	1.21	0.7	54.6	0.52	0.78	0.96	1.07	1.76	1.93

[a]SD = standard deviation.

[b]CV = coefficient of variation.

*[c]Outside fat = all subcutaneous outside round fat less than 1.3 cm.

[d]Outside fat (excess) = all subcutaneous outside round fat in excess of 1.3 cm.

**[e]Inside fat = all subcutaneous inside round fat less than 1.3 cm.

[f]Inside fat (excess) = all subcutaneous inside round fat in excess of 1.3 cm.

Table A-4 (continued)

[g]Seam fat = all intermuscular fat less than 1.3 cm.

[h]Seam fat (excess) = all intermuscular fat in excess of 1.3 cm.

[i]Total fat weight = outside fat + inside fat + seam fat + shank fat.

*(Outside round = center of the rectus femoris muscle to the end of the semitendinosus muscle).

**(Inside round = center of the rectus femoris muscle to the juncture of the semimembranosus and semitendinous muscles).

Table A-5. Simple Correlation Coefficients Relating Certain Carcass Characteristics

Trait	Carcass Length	Thorax Depth	Fat Thickness	Percentage KPH	Body-wall Thickness	Rib-eye Area	Yield Grade	Length of Eye	Width of Eye	Sarcomere Length
Carcass weight	.76**	.53**	.73**	.78**	.83**	.85**	.70**	.54**	.68**	.17
Carcass length		.61**	.29*	.48**	.85**	.59**	.34*	.52**	.40**	.11
Thorax depth			.24*	.33**	.33**	.33**	.21	.29*	.22	.03
Fat thickness				.68**	.86**	.62**	.89**	.36**	.52**	.21
Percentage KPH					.75**	.60**	.75**	.29*	.48**	.09
Body-wall thickness						.70**	.78**	.29*	.59**	.10
L. dorsi area							.41**	.70**	.81**	.18
U.S. yield grade								.15	.36**	.17
Length of eye									.47**	.09
Width of eye										-.12

*($P < 0.05$).

**($P < 0.01$).

Table A-6. Resgression Intercept and b Values for M:B-3

Equation	Independent Variable	Intercept	b Value	R^2	SEE[a]
1	Days on feed	3.64	.005	.24	.47
2	Days on feed	2.94	.039	.48	.28
	Breed		-.360		
3	Days on feed	2.48	.003	.51	.27
	Breed		-.332		
	Rib-eye area		.052		
4	Days on feed	2.46	.002	.52	.27
	Breed		-.323		
	Rib-eye area		.046		
	Adjusted fat thickness		.010		
5	Days on feed	2.41	.001	.52	.27
	Breed		.318		
	Rib-eye area		.035		
	Adjusted fat thickness		.010		
	Carcass weight		-.000		
6	Days on feed	2.69	.002	.52	.27
	Breed		-.325		
	Rib-eye area		.057		
	Adjusted fat thickness		.012		
	Carcass weight		3.262 E -.05		
	Fiber diameter		-.007		
7	Days on feed	3.106	.001	.54	.27
	Breed		-.327		
	Rib-eye area		.048		
	Adjusted fat thickness		.011		
	Carcass weight		5.815 E -.05		
	Fiber diameter		-.001		
	Percentage white fibers		-.009		
8	Days on feed	3.309	.003		
	Breed		-.358		
	Rib-eye area		.032		
	Adjusted fat thickness		.017		
	Carcass weight		-6.863 E -.05		
	Fiber diameter		-.003		
	Percentage white fibers		.007		
	Fat cell diameter		-.006		

[a]SEE = standard estimate of error.

Table A-7. Regression Intercept and b Values for M:B-5

Equation	Independent Variable	Intercept	b Value	R^2	SEE[a]
1	Days on feed	2.94	.004	.25	.34
2	Days on feed	3.50	.004	.49	.28
	Breed		-.373		
3	Days on feed	2.84	.002	.55	.27
	Breed		-.333		
	Rib-eye area		.075		
4	Days on feed	2.81	.001	.58	.26
	Breed		-.318		
	Rib-eye area		.651		
	Adjusted fat thickness		.076		
5	Days on feed	2.83	.001	.58	.26
	Breed		-.321		
	Rib-eye area		.070		
	Adjusted fat thickness		.018		
	Carcass weight		-.000		
6	Days on feed	3.01	.001	.58	.26
	Breed		-.336		
	Rib-eye area		.074		
	Adjusted fat thickness		.016		
	Carcass weight		-.000		
	Fiber diameter		-.004		
7	Days on feed	3.36	.001	.59	.27
	Breed		-.338		
	Rib-eye area		.067		
	Adjusted fat thickness		.015		
	Carcass weight		-.000		
	Fiber diameter		-.005		
	Percentage white fibers		-.007		
8	Days on feed	3.51	.003	.61	.26
	Breed		-.360		
	Rib-eye area		.055		
	Adjusted fat thickness		.020		
	Carcass weight		-.000		
	Fiber diameter		-.002		
	Percentage white fibers		-.006		
	Fat cell diameter		-.005		

[a]SEE = standard estimate of error.

Table A-8. Regression Intercept and b Values for M:B-1

Equation	Independent Variable	Intercept	b Value	R^2	SEE[a]
1	Days on feed	3.26	.004	.25	.40
2	Days on feed	3.84	.005	.43	.35
	Breed		-.385		
3	Days on feed	3.59	.004	.44	.35
	Breed		-.371		
	Rib-eye area		.028		
4	Days on feed	3.57	.002	.48	.34
	Breed		-.345		
	Rib-eye area		.012		
	Adjusted fat thickness		.027		
5	Days on feed	3.60	.002	.48	.34
	Breed		-.349		
	Rib-eye area		.020		
	Adjusted fat thickness		.027		
	Carcass weight		.000		
6	Days on feed	4.29	.003	.52	.33
	Breed		-.403		
	Rib-eye area		.041		
	Adjusted fat thickness		.021		
	Carcass weight		-.000		
	Fiber diameter		-.015		
7	Days on feed	4.26	.003	.53	.33
	Breed		-.402		
	Rib-eye area		.042		
	Adjusted fat thickness		.021		
	Carcass weight		-.000		
	Fiber diameter		-.015		
	Percentage white fibers		.001		
8	Days on feed	4.28	.003	.53	.34
	Breed		-.395		
	Rib-eye area		.045		
	Adjusted fat thickness		.021		
	Carcass weight		-.000		
	Fiber diameter		-.016		
	Percentage white fibers		.000		
	Fat cell diameter		.001		

[a]SEE = standard estimate of error.

Table A-9. Mean Values for Certain Yield Grade Factors

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
				Adjusted Fat Thickness					
Angus				4.06	8.60	13.00	12.20	13.20	16.40
Hereford				3.08	6.00	8.40	11.00	12.20	19.80
All	10.77	5.6	52.5	3.57	7.30	10.70	11.60	12.70	18.10
				Dressing Percentage					
Angus				53.20	58.30	58.70	60.90	62.10	62.90
Hereford				53.50	57.70	57.8	58.90	61.50	62.00
All	59.00	3.5	5.9	53.40	58.00	58.20	59.90	61.80	62.50
				Percentage KPH					
Angus				0.90	1.80	2.20	2.00	2.10	2.70
Hereford				1.00	1.40	1.50	1.30	1.80	2.20
All	1.74	0.6	10.1	0.95	1.60	1.85	1.65	1.95	2.45
				Rib-eye Area					
Angus				8.60	9.30	9.40	10.20	11.60	11.90
Hereford				8.20	8.40	9.00	9.00	11.40	11.70
All	9.9	1.8	18.5	8.40	8.90	9.20	9.60	11.50	11.80

Table A-9 (continued)

Breed	Overall			Days on Feed					
	Mean	SD[a]	CV[b]	0	28	56	84	112	140
				Final Quality Grade					
Angus				8.20	10.40	10.80	11.40	11.80	11.90
Hereford				7.20	8.80	9.60	8.40	10.40	12.40
All	10.2	2.1	20.6	7.70	9.60	10.20	9.90	11.10	12.20

[a]SD = standard deviation.

[b]CV = coefficient of variation.

VITA

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