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I am submitting herewith a thesis written by Dean A. Hutsell entitled "Identification of Factors Associated with Variability in Tenderness Among Beef Carcasses from Steers Differing in Breed, Body Type and Days on Feed." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

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Thesis

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IDENTIFICATION OF FACTORS ASSOCIATED WITH VARIABILITY
IN TENDERNESS AMONG BEEF CARCASSES FROM STEERS
DIFFERING IN BREED, BODY TYPE
AND DAYS ON FEED

A Thesis

Presented for the

Master of Science

Degree

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Dean A. Hutsell

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DEDICATION

With love and appreciation for their ever present praise and guidance, I joyfully dedicate this thesis to my parents, Mr. and Mrs. Frank Hutsell, Jr., whose interest and constant attitude of concern will always be cherished.

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ABSTRACT

Angus, Charolais and Hereford feeder steers (n=208) were measured and subjectively scored for physical production traits prior to being randomly assigned to groups fed a ration of either grain or silage. Steers were terminated from feed by predetermined criteria closely associated with carcass grade. The interval between succeeding slaughter groups was determined from fat and weight curves of similar calves from past studies (Montgomery, 1978). Calves were slaughtered when the mean fat thickness (12th rib) for all steers in a pen (n=7 or 8) reached approximately 12 mm. Short loin steaks were removed from each carcass 10-14 days postmortem to facilitate palatability evaluations. Loin steaks were rated "slightly tender to moderately tender" for all breed and feeding regime groups by an 8-member, trained sensory evaluation panel. Frozen muscle fragmentation index was linearly related to days on feed for grain fed steers. Approximately 21% of the observed variation in WBS force values was attributed to environmental effects, marbling degree, and frozen muscle fragmentation index. Acceptable palatability of loin steaks (regardless of breed, body type, degree of muscling or feeding regime) is achieved when steers were fed to a 12 mm subcutaneous fat level.

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CHAPTER I

INTRODUCTION

The cattle industry in the United States has evolved over the past 150 years, resulting in dominant changes in the preferred cattle type. Long ago, cattle were produced primarily for their hides and byproducts. Since then, values have changed, and today the dressed carcass represents 90% of the animal's value. Cattlemen have genetically altered beef animals to make them more suitable for modern trade and retain their utility on the farm. Thus, the animals capable of efficient feed conversion into the maximum amount of acceptable meat products are most desired (Hedrick, 1972).

Carcass quality is an important factor in beef marketing and is associated with differences in animal composition, age and sex. The primary palatability attributes are meat tenderness and juiciness, which are highly associated with consumer acceptance (Berg et al., 1968). Therefore, in order to satisfy the consumer, beef must be tender, juicy, flavorful and yet possess a minimum of waste fat and be priced competitively with other meat products (Hedrick, 1972).

Realizing that carcass quality is highly related to consumer acceptance and meat value, we must be concerned with carcass composition. Composition refers to the proportions of major carcass tissues (fat, bone and muscle). Proportional carcass composition can be influenced by animal age, weight, breed, nutrition or environmental conditions (Berg et al., 1968).

Note: The citations on the following pages follow the style of the Journal of Food Science.

Cattle type has developed into a major concern for beef producers. It is important to realize that of all A maturity beef, 97% is produced via the feedlot (Crouse and Smith, 1978).

Price discrimination is lessening (Menkhaus and Kearl, 1976), thus, there is a need to further elucidate the relationship between body type, feeding time and level of finish at which any particular type will yield the optimum grade and quality.

A need exists to further study the interrelationship among time on feed, feeding regime, U.S. yield and quality grade, breed and cooked meat palatability. The objectives of the present study were as follows:

1. To determine the minimum days on feed required to produce a yield grade 2 choice carcass with an acceptable cooked product from steers grouped according to breed, weight and body type;
2. To characterize certain physical, chemical and histological traits of muscle from steers grouped according to breed, weight and body type.

CHAPTER II

LITERATURE REVIEW

Crouse and Smith (1978) emphasized that of animals on feed today, 97% are of A maturity, that fat level in young beef is not as critical to quality grade as it is in more mature beef; and, that young beef is more tender than beef from physiologically mature animals. However, degree of intramuscular fat has been shown to be related to meat tenderness (Crouse and Smith, 1978; Campion et al., 1975; Breidenstein et al., 1968; Goll et al., 1965; Blumer, 1963). In addition, carcass maturity (Berry et al., 1974a,b; Adams and Arthaud, 1970; Schmidt et al., 1970; Breidenstein et al., 1968; Romans et al., 1965), quantity of connective tissue (Ritchey and Hostetler, 1965; Cover et al., 1962; Goll et al., 1963), fiber diameter (Herring et al., 1965a; Swanson et al., 1965; Tuma et al., 1962; Cover et al., 1962), Sarcomere length (Bouton et al., 1973; Howard and Judge, 1968; Gothard et al., 1966; Herring et al., 1965a,b; Locker, 1960), waterholding capacity (Covington et al., 1970; McClain and Mullins, 1969; Breidenstein et al., 1968; Ritchey, 1965; Grau and Hamm, 1953) and carcass suspension methods (Bouton et al., 1973; Hostetler et al., 1970) all have been related to meat tenderness. Results of these studies have shown that these factors are related to but not highly correlated with tenderness.

Szczesniak and Torgeson (1965) and Pearson (1966) reviewed methods that objectively evaluate bovine meat tenderness. Warner (1928) developed a mechanical means of cooked meat tenderness evaluation. Later it was refined by Bratzler (1949) and established as the Warner-Bratzler shear.

Other mechanized methods have been developed that evaluate fresh muscle. These include the Armour Tenderometer (Parrish et al., 1973), Nip Tenderometer (Smith and Carpenter, 1973; Davis et al., 1975) and Fragmentation Index (Davis et al., 1978; Calkins and Davis, 1978; Olson et al., 1976; Møller et al., 1973; Fukazawa et al., 1969; Takahashi et al., 1967). Of these methods, fragmentation index appears to show promise in tenderness determination of raw muscle.

Smith et al. (1977) indicated that the eventuality of reduced feed grain usage would necessitate identification of feeding systems that would produce maximum quantities of acceptable beef per unit of resource input. Using selected steers of various breed combinations and body type, these researchers considered growth related to feed efficiency as the animals were serially slaughtered. They found that large framed steers possessed slightly lower palatability scores at constant weight but not at constant age or fat compositional endpoint. These researchers concluded that small type steers matured faster as well as graded higher than large type steers slaughtered at the same age. Bowling et al. (1977) compared forage and grain finished beef possessing the same maturity and intramuscular fat levels but varied subcutaneous fatness. This study identified the problem of appropriate slaughter endpoints, stressing that if animals are slaughtered on a time-constant basis, fat level would obscure the actual differences in palatability and, if at the same subcutaneous fat level, maturity differences would affect the analysis. The study also indicated that flavor problems associated with grass fed steers would disappear after 49 days on either a 40 or 80% grain ration. In addition, carcasses with subcutaneous fat levels between 1.27 mm and 10.2 mm increased in tenderness as fat level increased.

Thus, it is obvious that a specific mature chronological age for various physiological animal types, fed a certain energy level, can be established. The minimum feed input for acceptable beef quality can be determined, therefore reducing time on feed and costs.

CHAPTER III

EXPERIMENTAL PROCEDURE

Steer (Angus, Hereford, Charolais) calves (n=208) weighing 205-227 kg were selected in October 1977 and randomly assigned within breed to groups based on ration energy level and predicted maturing rate. The steers were weighed, somoscoped, measured and photographed prior to division into groups. Ultrasonic estimates of fatness were obtained by use of a sonar. They were taken over the longissimus dorsi at the 12th and 13th rib interface three-fourths the distance between the dorsal midline and distal edge. This procedure was done initially, at 25 days on feed, 61 days on feed and then every 14 days until steers were slaughtered.

Each calf was photographed in a specially designed grid chute and measured at a later date. Strategic measuring endpoints (point of shoulder, hook bone and pin bone) were paint branded prior to entering the grid chute. The following measurements were obtained for all steers (Figure 1):

1. Height at withers (HW)--from the base of the grid chute to the dorsal top line of the withers;
2. Length of body (LB)--from the anterior point of the shoulder to the posterior ischium.
3. Depth of body (DB)--the shortest distance from the chest floor to the topline measured posterior to the forearm.

Postmortem carcass evaluation for U.S.D.A. (1976) grade factors and certain quality indicators was performed 72 hrs postmortem. The

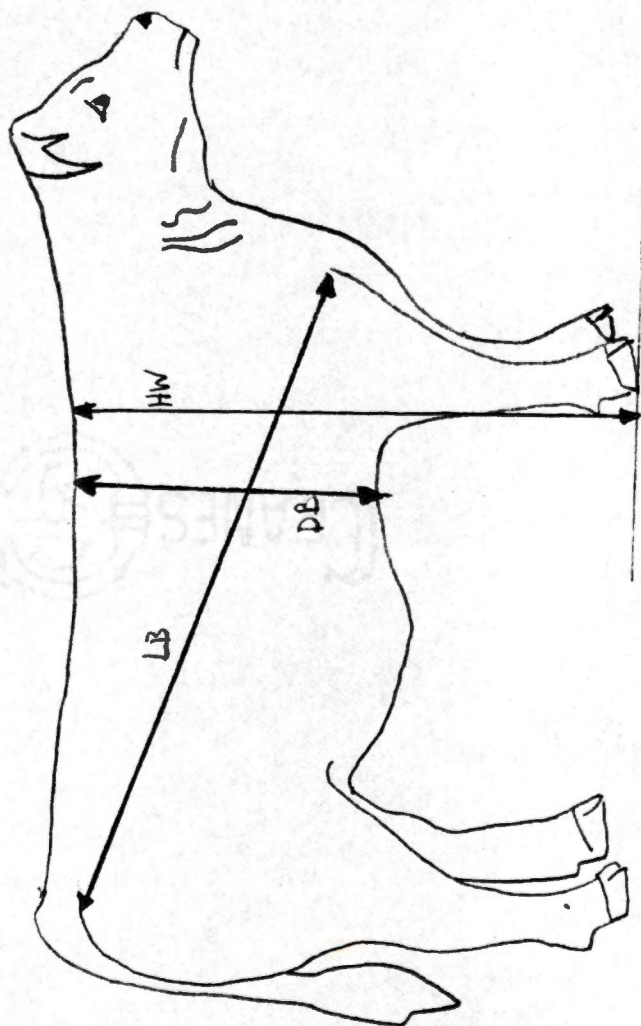


Figure 1. Strategic endpoints utilized for feeder calf body measures.

carcasses were aged 10-14 days in a 2°C cooler. Five steaks (A, 1.27 cm thickness; B and C, 0.65 cm thickness; D and E, 3.2 cm thickness) were removed from the anterior end of the shortloin for chemical (steak A), physical (steaks B and C), histological (steak B) and palatability (steaks D and E) analysis.

Carcass Evaluation

University of Tennessee personnel evaluated each carcass for U.S. quality and yield grade factors. Also, subjective evaluations of the carcasses for the following quality indicators were performed: lean color; lean firmness; lean texture; marbling texture; marbling distribution; and marbling size variability using 8-point rating scales (8 = light grayish red, very firm, very fine texture, very even distribution and very uniform size; 1 = black, very soft, very coarse texture, very uneven distribution and extremely variable in size). Conformation score (CH° = 13, CH+ = 14) and fat color score (5 = white, 1 = yellow) also were evaluated (see Appendices G, H and I).

Proximate Analysis

Proximate analysis samples (steak A) were trimmed of all epimyseal tissue, cubed, frozen in liquid nitrogen and then powdered in a Waring blender. Percent moisture was determined by use of a 100°C vacuum oven. Samples were dried 8-12 hours and then fat extracted with anhydrous ether in a soxhlet fat extraction apparatus. Percent fat was computed for both whole tissue basis (WTB) and moisture free basis (MFB). A.O.A.C. (1975) procedures were followed (see Appendices A and B).

Fragmentation Index

The procedure of Davis et al. (1978) modified by Calkins (1978) was followed. Index of fragmentation was obtained by adding 10 g of 7 mm cubed longissimus dorsi muscle (fresh, steak B or frozen, steak C) to 50 ml of cold sucrose (0.25 M) potassium chloride (0.02 M) solution in a 150 ml fluted, stainless steel homogenization cup. After 5 minutes in the solution, each sample was blended for 40 seconds at full speed (100%) using a Virtis Macro-Model "45" homogenizer. The blades were attached in reverse position and parallel with the dorsal blade positioned in the surface of the solution. The homogenate was filtered through a 250 mm pore size "Nitex" screen positioned in a modified 115 ml "Nalgene filter unit" with the aid of a plastic stirring rod. Screen and residue were blotted on Whatman No. 3 filter paper and allowed to air dry at 22°C for 10 minutes after which residue weights were calculated. Fragmentation index = 100 x residue weight in grams (see Appendix C).

Expressible Juice

From steak B duplicate 500 mg samples of fresh longissimus dorsi muscle were pressed according to the press method of Grau and Hamm (1953) as modified by Briskey et al. (1959) to evaluate water-holding capacity. A Carver laboratory press was used to apply a pressure of 4000 psi for 5 minutes to each sample. Percent expressible juice was calculated using the formula derived by Carpenter (1962) (see Appendix D).

$$\% \text{ expressible juice} = \frac{\text{total juice area} - \text{meat film area}}{\text{total moisture (mg) in original muscle sample}} \times 44.07$$

Sarcomere Length

From steak B, samples for sarcomere length determination were obtained and fixed in a 4% neutral formalin solution. They then were

blended in an Osterizer cycle-blend for 2 minutes with 25 ml of 4% neutral formalin solution for 2 minutes. A light microscope equipped with a filar micrometer (magnification = 1500X) was used to measure 10 sarcomeres on each of 12 myofibrils (see Appendix E).

Cookery

Steaks D (shear force evaluation) and E (sensory evaluation) each were wrapped in polyethylene coated freezer paper, frozen at -23°C , stored at -4°C , and then allowed to thaw for 24 hours in a $5-7^{\circ}\text{C}$ cooler prior to cooking (see Appendices F and G). Four 1.3 cm cores were removed from steak D, cooled to 25°C and subsequently sheared twice each on a Warner-Bratzler shear apparatus. A trained, 8-member sensory panel evaluated tenderness, juiciness, connective tissue amount, flavor intensity, flavor desirability and overall desirability for all samples according to 8-point rating scales (8 = extremely tender, extremely juicy, no connective tissue, extremely intense beefy flavor, extremely desirable flavor and extremely desirable overall; 1 = extremely tough, extremely dry, abundant connective tissue amount, extremely intense milky flavor, extremely undesirable flavor and extremely undesirable overall). Also, degree of doneness for both steaks D and E was recorded using an 8-point scale (8 = extremely well done, 1 = extremely rare).

Statistical Design and Analyses

Angus, Hereford and Charolais feeder calves ($n=208$) representing the entire range of predicted maturing rates, predicted carcass weights and frame types (compact, $n=78$; average, $n=90$; growthy, $n=40$) were purchased. Following division according to breed, maturing rate and size, they were randomly divided into two ration energy levels. Within

ration treatment groups, animals were divided into kill groups of 6 animals each on the basis of predicted days on feed to reach 12 mm subcutaneous fat. Kill groups were serially slaughtered for time intervals intended to span grade levels of U.S. Standard to Choice-plus.

Statistical Analysis System (SAS), developed by Barr and Goodnight (1972) was utilized in obtaining means, ranges, coefficients of variation, simple and partial correlation coefficients and multiple regression analyses.

CHAPTER IV

RESULTS AND DISCUSSION

Angus, Hereford and Charolais steers (n=208) are characterized by means and coefficients of variation (Table 1). Charolais calves utilized in the current study possessed higher frame scores and yielded heavier carcasses than Angus or Hereford calves. However, there were no important differences among the breeds or between feeding regimes for overall maturity, fat thickness, quality grade, yield grade, shear or tenderness rating (Table 1). Overall coefficients of variation for selected characteristics ranged from approximately 9% for overall maturity to 35% for fat thickness. Overall frame score was the most variable (C.V. = 49.0) characteristic among the breeds (Table 2). In the interpretation of these data one must recognize that steers were selected for serial slaughter from 3 to 25 mm subcutaneous fat in an effort to yield a pen average of 12 mm on all pens.

Presented in Table 2 are selected means for steers segregated into three groups by frame score (Frame 1 = compact; Frame 2 = average; Frame 3 = growthy). These data indicate that steers which were more growthy (higher frame scores) possessed heavier carcasses with less subcutaneous fat. In addition, Warner-Bratzler shear force values and tenderness ratings show only slight differences for steers of all body types. Flavor evaluations indicate this criteria of meat palatability to be equivalent for all frame sizes (Table 2).

Initial and final live mean weights for grain and silage fed steers (Angus, Hereford and Charolais) are represented graphically in

Table 1--Means and coefficients of variation (C.V.) for feeder calf frame score, certain carcass characteristics and tenderness evaluations grouped according to breed and feeding regime

Breed and Treatment	n	Frame score ^a		Overall ^b maturity		Carcass weight (kg)		Fat thickness (mm)		U.S. quality grade ^c		U.S. yield grade		Warner-Bratzler shear (lb)		Tenderness rating ^d	
		$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.	$\bar{x}$	C.V.
Overall mean	208	7.4	48.7	14.1	9.2	235.2	15.4	9.4	35.5	11.9	14.3	2.5	24.0	6.6	33.0	5.7	14.0
Angus ^e																	
Grain	35	5.3	45.3	13.7	11.0	225.4	12.5	9.4	29.5	12.4	14.5	2.6	15.4	7.3	27.2	5.8	15.5
Silage	36	5.6	48.2	14.1	8.5	224.9	13.4	9.7	30.2	12.4	11.3	2.6	19.2	6.2	32.1	5.7	12.3
Hereford ^f																	
Grain	34	5.7	38.6	13.8	10.9	221.4	12.7	10.7	36.5	10.8	17.6	2.7	25.9	6.6	36.7	5.8	15.5
Silage	36	6.4	43.8	14.1	7.1	216.3	12.4	8.9	40.0	11.0	13.6	2.5	20.0	7.3	36.4	5.5	16.4
Charolais																	
Grain	33	10.7	29.9	14.3	10.5	268.3	16.0	9.1	47.3	12.4	10.5	2.4	29.2	6.8	32.3	5.7	14.0
Silage	34	10.9	28.4	14.7	8.2	254.8	11.6	7.4	32.4	11.7	14.5	2.3	21.7	5.7	30.8	5.7	14.0

^a15 point rating scale: 1 = -1; 15 = +5 (see Appendix J).

^b_A30 = 13, _A40 = 14.

^c10 = Gd⁰; 13 = Ch⁰.

^d8 point rating scale: 8 = extremely tender; 1 = extremely tough.

^eAngus WBS and tenderness, n = 34 for grain-fed; n = 35 for silage-fed.

^fHereford WBS and tenderness, n = 33 for grain-fed; n = 36 for silage-fed.

Table 2--Selected means ($\bar{x}$), standard deviations (S.D.) and coefficients of variation (C.V.) for calves segregated by frame score

	Frame 1 ^a			Frame 2 ^b			Frame 3 ^c		
	$\bar{x}$	S.D.	C.V.	$\bar{x}$	S.D.	C.V.	$\bar{x}$	S.D.	C.V.
Carcass weight (kg)	216.3	26.0	12.0	234.2	32.0	13.7	270.0	36.5	13.5
Carcass fat (mm)	10.2	2.8	28.7	9.1	3.3	36.3	7.9	3.8	48.2
Warner Bratzler shear (lb)	6.8	2.2	32.4	6.6	2.2	33.3	6.4	2.0	31.3
Tenderness rating ^d	5.8	.9	15.4	5.7	.8	13.5	5.7	.9	15.5
Flavor desirability ^d	6.0	.5	9.1	5.8	.6	10.8	6.0	.6	10.0

^aFrame 1 = scores 1-5, corresponds to compact calves.

^bFrame 2 = scores 6-10, corresponds to average calves.

^cFrame 3 = scores 11-15, corresponds to growthy calves.

^d8-point rating scales: 8 = extremely tender, desirable flavor; 1 = extremely tough, undesirable flavor.

Figure 2. Numbers represent initial weights (1 and 3) of the time steers were placed on feed and final weights (2 and 4) prior to slaughter. These bar graphs indicate steers averaged approximately 260 kg when placed on feed and finished at an average of approximately 500 kg. Charolais steers were slightly heavier at slaughter. Note that these are mean carcass weights.

Figure 3 represents mean tenderness ratings and Warner-Bratzler shear force values for feeder calves versus days on feed. Taste panel ratings fluctuated similarly with changes in shear force values. Calves slaughtered at approximately 150 days of age produced slightly less tender loin steaks. Overall, calves did not vary extremely in tenderness ratings or shear force values (Figure 3).

Presented in Table 3 are simple correlation coefficients among selected chemical, histological and sensory characteristics. A significant ($P < .001$) correlation of -0.67 (Table 3) between shear force value and sensory tenderness rating was higher than that reported by Breidenstein et al. (1968) and Goll et al. (1965) but lower than by Calkins (1978) and Matthews and Bennett (1962). Frozen fragmentation index was significantly ($P < .001$) related to tenderness ($r = -.23$, $P < .01$) and shear force value ($r = .28$, $P < .001$). Calkins (1978) reported higher correlations ($r = -.68$, $P < .01$) and ($r = .71$, $P < .01$) for tenderness ratings and Warner-Bratzler shear force value with frozen fragmentation respectively. Hiner et al. (1945) explained that increased tenderness ratings for frozen samples were possibly enhanced by formation of intrafibrillar ice crystals that disrupt muscle fibers and interstitial connective tissues. In addition, catheptic enzymes which are released from ruptured lysosomes may induce a slight tenderization advantage for frozen steaks upon thawing

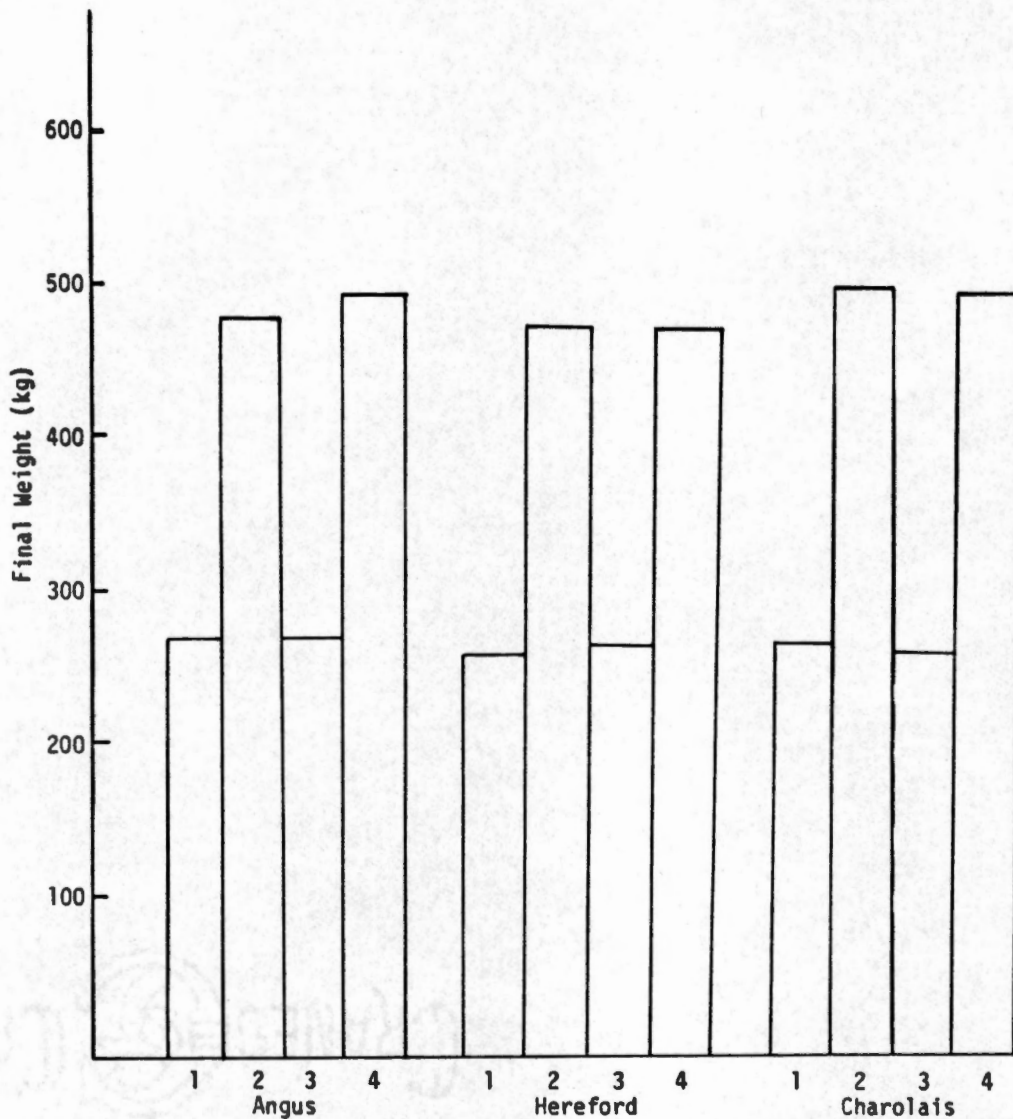


Figure 2. Initial and final mean live weights for grain and silage fed Angus, Hereford and Charolais steers.

- 1 = Grain-fed, initial mean weight
- 2 = Grain-fed, final mean weight
- 3 = Silage fed, initial mean weight
- 4 = Silage fed, final mean weight

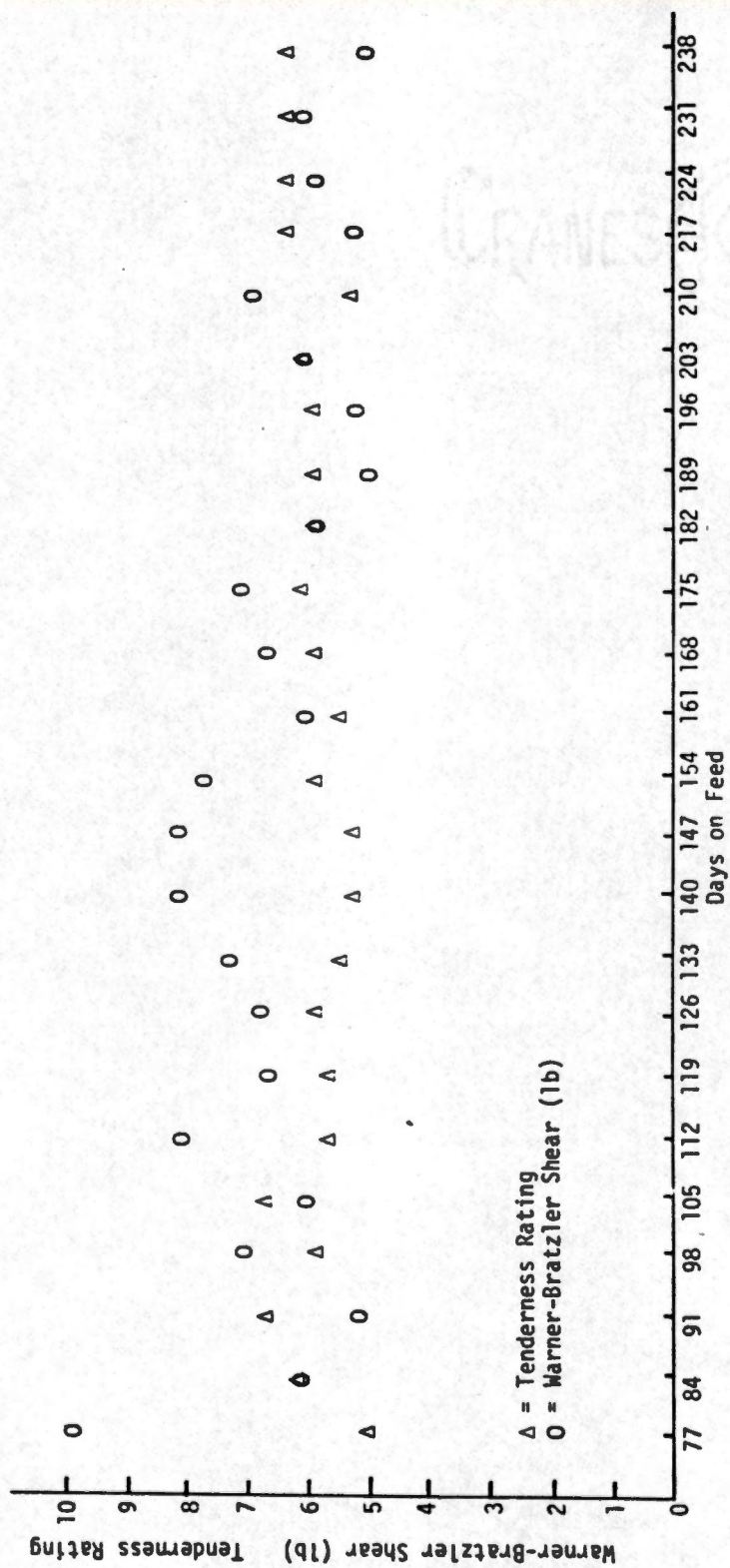


Figure 3. Mean tenderness ratings and Warner-Bratzler shear force values for all steers fed 77 to 238 days.

Table 3--Simple correlation coefficients among selected chemical, histological and sensory characteristics
(n=208)

Characteristic	Fresh frag- mentation index	Fresh frag- mentation index	Expressible juice (%)	Chemical Fat (%,WTB)	Moisture (%)	Tenderness	Warner- Bratzler shear (lb)
Sarcomere length (μ) ^a	.02	-.13	-.02	.06	-.09	.09	-.21
Fresh fragmentation index		*** .50	-.03	*** .27	*** -.40	-.02	-.08
Frozen fragmentation index			-.06	** .21	*** -.27	** -.23	*** .28
Expressible juice (%)				** .20	-.13	-.12	-.05
Chemical fat (% , WTB) ^b					*** -.89	.09	-.13
Moisture (%)						-.13	** .20
Tenderness ^c							*** -.67
Warner-Bratzler shear (lb)							--

^a Sarcomere length correlations were for the longissimus muscle from Hereford steer carcasses (n=68).

^b WTB = white tissue basis.

^c Tenderness 8-point rating scale: 8 = extremely tender; 1 = extremely tough.

*P<.05; **P<.01; ***P<.001.

(Bailey, 1972). Further data presented in Table 3 show correlation results for fresh fragmentation index with frozen fragmentation index lower (.50, $P < .001$ vs. .71, $P < .01$) than those reported by Calkins (1978). Perhaps this relationship is a result of evaluations obtained for A maturity steer carcasses instead of a wide maturity range including C and D maturity carcasses.

Simple correlation coefficients among selected carcass characteristics are reported in Table 4. Marbling degree increased with carcass weight ($r = .49$). Correlations among carcass characteristics evaluated by Crouse and Smith (1978) show r -values which vary from those obtained in the present study. A higher value ($r = .66$) for marbling degree versus fat thickness was obtained by these researchers. Ribeye area versus marbling degree ($r = .21$) and adjusted fat thickness ($r = .21$) indicate differences in calves utilized in the study conducted by Crouse and Smith (1978) and this study.

Sensory relationships in Table 5 indicate attributes scored by the panel were significantly related to each other. Few significant correlations were observed relating cooking time to palatability. Low but significant relationships exist between juiciness score, overall satisfaction and cooking time, thus suggesting that palatability was slightly altered by cookery procedure. Tenderness and flavor desirability were related ($r = .75$ and $r = .77$, respectively) to overall satisfaction.

Breed and treatment were factors which affected the relationship between carcass weight and adjusted fat thickness (Table 6). As days on feed progressed and steers increased in weight, it was noted that breed and treatment did not effect a change in the relationships of these variables with shear force value and lean texture. Uniformity of

Table 4--Simple correlation coefficients among selected carcass characteristics (n=208)

Characteristic	Lean texture	Lean firmness	Marbling degree	Marbling texture	Marbling distribution	Marbling variability	Estimated ribeye fat (%)	Lean maturity	Estimated tenderness	Ribeye area	Fat thickness (carcass)	Carcass weight
Lean color ^a	^{**} .40	.07	.06	^{**} .23	.08	.13	.07	^{**} .70	.11	-.01	-.12	-.05
Lean texture ^a		-.01	.09	^{**} .26	.08	.10	-.09	^{**} .46	-.13	-.09	-.07	-.19
Lean firmness ^a			^{**} .42	-.01	.19	.09	^{**} .42	-.05	^{**} .29	.06	.22	.22
Marbling degree ^b			-.01	-.01	^{**} .52	^{**} .34	^{**} .49	.13	^{**} .58	^{**} .37	^{**} .26	^{**} .49
Marbling texture ^a					^{**} .43	^{**} .58	-.02	-.20	.02	-.08	-.14	-.06
Marbling distribution ^a						^{**} .61	^{**} .52	.08	^{**} .38	.21	.06	^{**} .23
Marbling variability ^a							^{**} .33	-.01	^{**} .29	.09	-.04	.07
Estimated ribeye fat (%)								.11	^{**} .60	^{**} .37	^{**} .26	^{**} .46
Lean maturity ^c									.11	.17	.19	^{**} .27
Estimated tenderness ^d										^{**} .34	^{**} .23	^{**} .44
Ribeye area (in ²)											-.03	^{**} .72
Fat thickness (carcass, mm)												^{**} .25
Carcass weight (kg)												--

^a 8 point rating scales: 8 = light grayish red, very fine, very firm, very uniform, very uniform size; 1 = black, very coarse, very soft, very uneven, extremely variable size, respectively.

^b Devoid¹⁰ = 1; Abundant⁹⁰ = 99.

^c Calf¹⁰ = 1; E¹⁰⁰ = 60.

^d 3 point rating scale: 1 = tender, 2 = acceptable, 3 = tough.

*P<.05; P<.01; P<.001.

Table 5--Simple correlation coefficients among selected sensory and cookery characteristics (n=208)

Characteristic	Warner-Bratzler shear	Flavor desirability	Flavor description	Connective tissue amount	Juiciness	Overall satisfaction	Cooking time
Tenderness ^a	*** -.67	*** .42	** .28	*** .62	** .28	*** .75	-.11
Warner-Bratzler shear (lb)		*** -.28	* -.22	* -.27	.06	*** -.47	-.06
Flavor desirability ^a			*** .88	*** .43	*** .26	*** .77	-.13
Flavor description ^a				---	*** .31	*** .71	-.06
Connective tissue amount ^a					-.19	*** .62	.07
Juiciness ^a						*** .49	** -.20
Overall satisfaction ^a							* -.15
Cooking time (min)							--

^a8-point rating scales: 8 = extremely tender, desirable, intense beefy, juicy, no connective tissue; 1 = extremely tough, undesirable, intense milky, dry, abundant connective tissue, respectively.

*P<.05.

**P<.01.

***P<.001.

Table 6--Partial and simple correlation coefficients for certain live, carcass, chemical and physical characteristics (n=208)

	Code	1 ^a	2	3	4	5	6	7	8	9	10
Frame score ^c	1 ^b		.55**	-.25**	.44**	--	-.20*	--	--	.46**	--
Carcass weight (kg)	2	.35**		.25**	.72**	.49**	-.19*	.36**	-.19*	.76**	--
Adjusted fat thickness (mm)	3	.12	.45**		--	.26*	-.07	.30**	--	.15*	--
Ribeye area (in ²)	4	.19*	.63**	--		.37**	--	.24**	--	.50**	--
Marbling degree ^d	5	--	.51**	.36**	.37**		--	.81**	-.21*	.40**	--
Lean texture	6	-.14	-.17*	.19*	--	--	--	-.11	--	-.30**	--
Chemical fat (%WTB) ^f	7	--	.43**	.27**	.31**	.81**	-.16*	--	--	.26**	--
Warner-Bratzler shear (lb)	8	--	-.20*	--	--	-.20*	--	--	--	-.26**	-.67*
Days ^g	9	.25*	.79**	.38**	.50**	.49**	-.23*	.37**	-.27**	--	--
Tenderness	10	--	--	--	--	--	--	--	-.64**	--	--

^aAbove diagonal are overall (r) characteristics.

^bBelow diagonal are residual (R) correlations, $\hat{y}$ = breed and treatment.

^c15 point rating scale: 1 = +1; 15 = +5 (see Appendix J).

^dDevold¹⁰ = 1; Abundant⁹⁰ = 99.

^e8 point rating scale: 8 = very fine, extremely tender, respectively; 1 = very coarse, extremely tough, respectively.

^fWTB = whole tissue basis.

^gDays on feed.

*P<.05; **P<.001.

finish (quality grade C.V. = 14.5%) for steers utilized in this study may explain this relationship. Since marbling degree and fat thickness increase with higher carcass weights and days on feed, it follows that intramuscular fat deposition may be somewhat cancelling the toughening effect of the coarser textured muscle. Blumer (1963) reported intramuscular fat content to be responsible for approximately 5% of the variation in tenderness ratings. Goll et al. (1965) indicated no relationship between tenderness and fat measures utilized in their study. Because of the low relationship of intramuscular fat content with tenderness, it follows that some other factor is producing a tenderizing effect. Further data (Table 6) show that no significant relationship exists between intramuscular fat (actual %, WTB) and tenderness or shear force value. This agrees with findings of Romans et al. (1965) and Goll et al. (1965). However, Davis (1977) reported a significant relationship between intramuscular fat (actual %, WTB) and tenderness and shear value.

Figures 4 and 5 graphically present tenderness ratings and Warner-Bratzler shear values versus days on feed. Points represented were obtained by the summation of values in five divisions (1=up to 100 days, 2=from 100 to 150 days, etc.) from scatter diagrams. Tenderness rating (Figure 4) for both grain and silage-fed steers indicates slightly less tender loin steaks were produced from steers fed 125 days to 200 days. Correspondingly, Warner-Bratzler shear values appeared to follow a similar pattern (Figure 5). Thus, the relationship of days on feed regardless of ration indicates a period where a slight toughening effect is observed. Zinn et al. (1970) reported similar results. Grain-fed steers appeared, in general, to be slightly more variable in tenderness than those fed the silage ration (Figures 4 and 5).

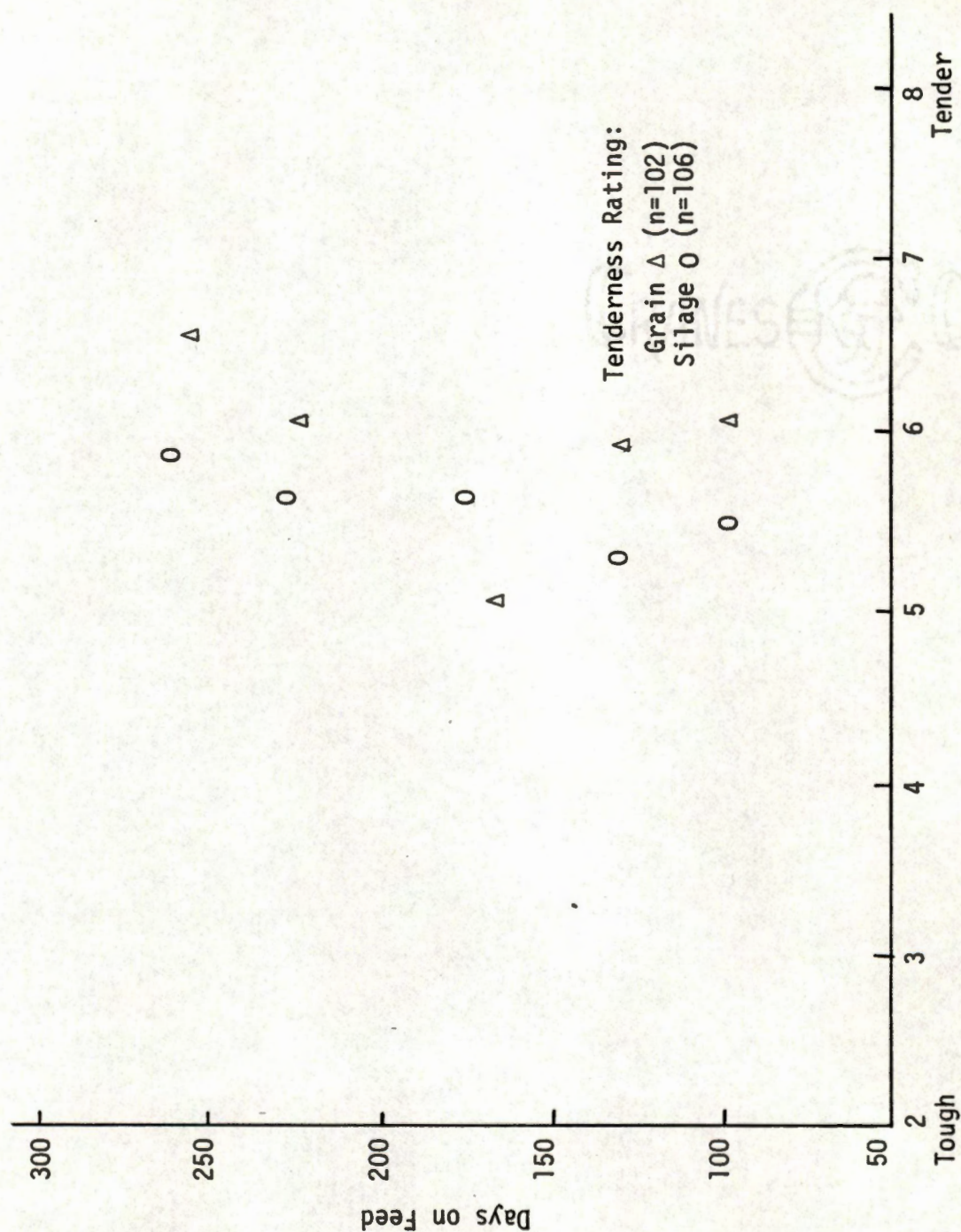


Figure 4. Graphical representation of tenderness rating for grain and silage fed steers versus days on feed.

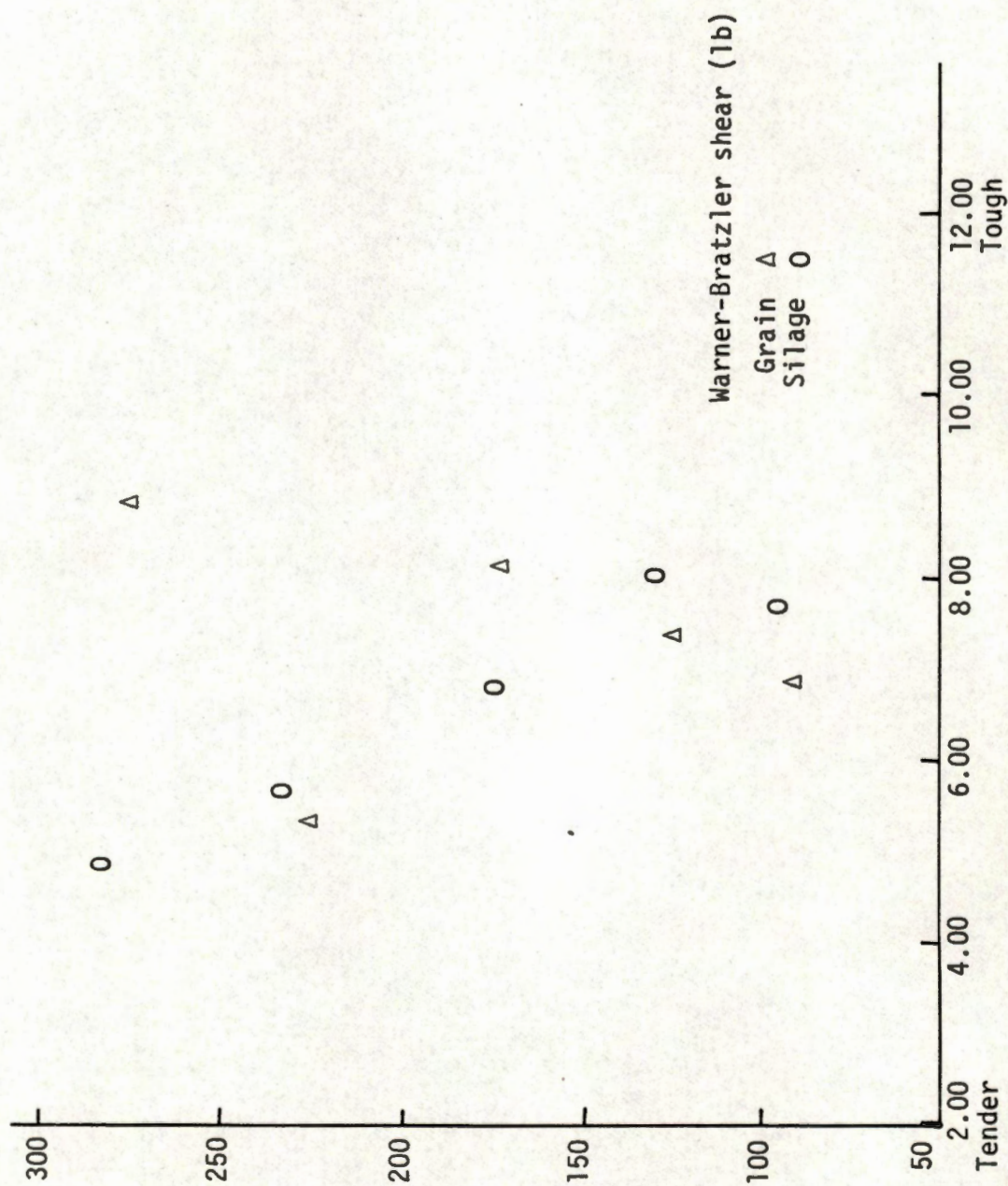


Figure 5. Graphical representation of Warner-Bratzler shear values versus days on feed.

Represented in Figure 6 is a comparison of Warner-Bratzler shear (WBS) values and tenderness ratings for grain and silage-fed Angus, Hereford and Charolais feeder steers. This graph illustrates WBS values and tenderness ratings for tender and less tender samples segregated the population of feeder steers similarly.

Fresh and frozen fragmentation data for grain and silage-fed steers at progressive intervals (Figure 7) indicate that the fragmentation procedure for fresh and frozen meat samples varies. Representations for fresh and frozen indices in Figure 7 indicate as days on feed progressed, residue weights became slightly higher, suggesting slightly less tender loin steaks. Further examination indicates that grain-fed steers produced residues, in general, that were heavier than those for silage-fed steers for both procedures (Figure 7). These data indicate that physiological changes occurring in the musculature and its connective tissue components may be responsible for the slight differences in residue weights (Bailey, 1972).

Results of multiple regression analyses presented in the following tables were the best models obtained for the variables of interest in predicting four dependent variables (Warner-Bratzler shear, tenderness rating, fresh and frozen fragmentation index). All discrete by continuous interactions were tested in preliminary analyses and nonsignificant interactions were deleted from the models. Those interactions approaching significance were considered and further tested before being left in or deleted from the final models. Breed and treatment were considered in all models and remained, whether significant or nonsignificant, as they were fixed environmental effects.

Regression analyses for the dependent variables Warner-Bratzler

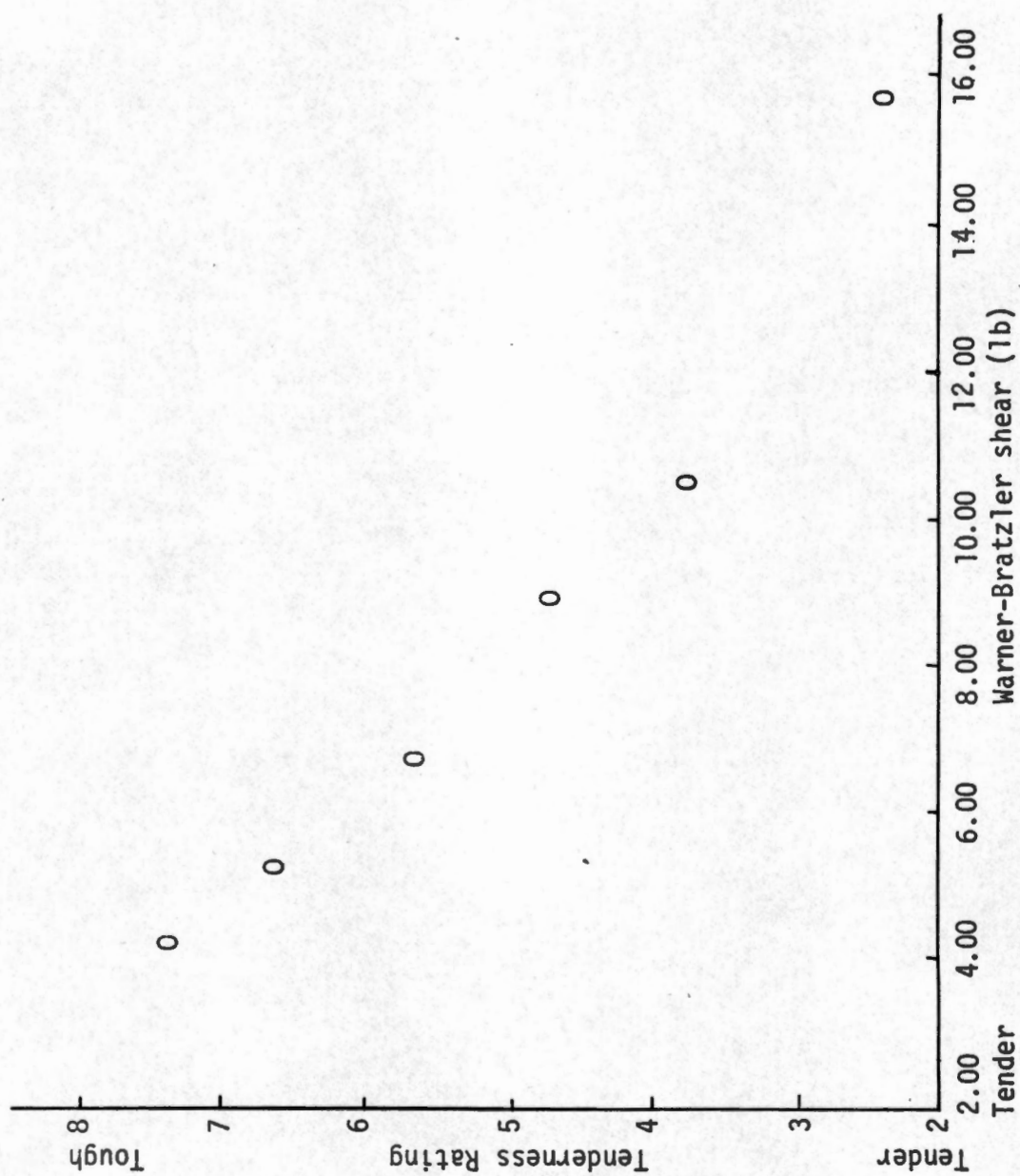


Figure 6. Graphical representation of tenderness ratings versus Warner-Bratzler shear force values (n=208).

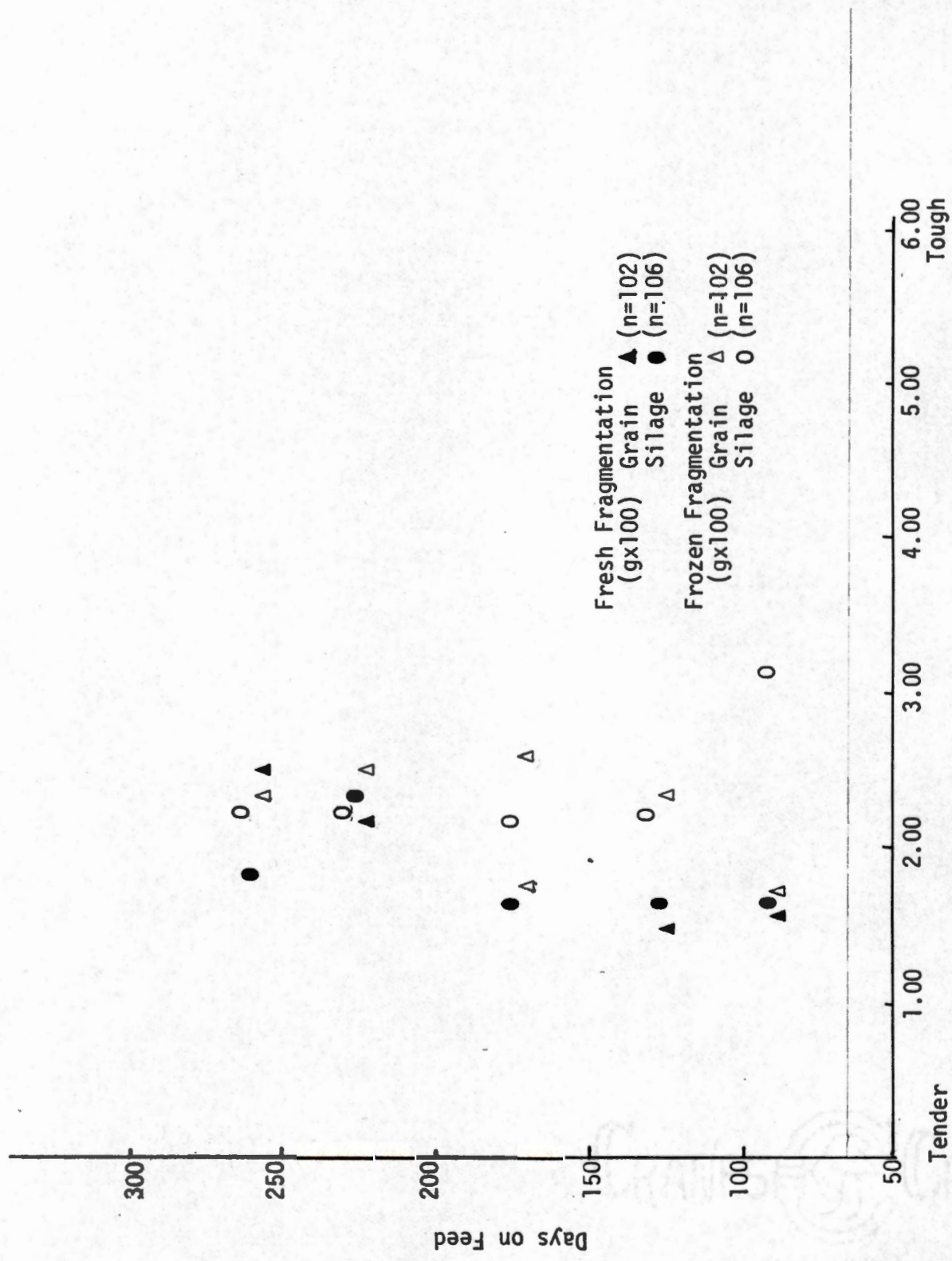


Figure 7. Graphical representation of fresh and frozen fragmentation index for grain and silage-fed steers versus days on feed.

shear (WBS), tenderness rating, fresh and frozen fragmentation with objective live measures, sale weight, and days on feed are presented in Table 7. Fat level obtained by use of a somoscope, days on feed and days on feed squared accounts for 13.08% (Table 7) of the variation in WBS values. Since fat thickness was included in the model (Table 7) and contributed significantly to the variation in WBS values (.34, $P < .05$), it is suggested that initial subcutaneous fat thickness is slightly associated with tenderness.

Tenderness rating regressed on these same independent variables (Table 7) indicated only 3.14% of the observed variation in taste panel evaluation could be attributed to live animal characteristics. Thus, none of the feeder calf measures were significantly related to sensory tenderness evaluation (Table 7).

Objective live animal measures were not related to fresh fragmentation values and were deleted early in regression analyses. However, days on feed contributed significantly to variation in fresh fragmentation index (Table 7). These results suggest as animals become older more connective tissue is deposited and the body composition is simultaneously changing (Bailey, 1972; Cover et al., 1962).

Live animal length was the only feeder calf live measure contributing to variation in frozen fragmentation index (Table 7). These data indicate longer animals are responsible for variation in residue weights and suggest that animals initially longer in body length produced slightly less tender loin steaks.

Least squares means presented in Table 7 suggest Angus, Hereford and Charolais to be similar in tenderness regardless of ration fed. Examination of least squares means (Table 7) for fresh and frozen

Table 7--Partial regression coefficients and least squares means for equations predicting Warner-Bratzler shear, tenderness rating, fresh and frozen fragmentation index from objective live measurements, sale weight and days on feed

Model	Warner-Bratzler shear (lb)	Dependent variables		
		Tenderness rating	Fresh fragmentation	Frozen fragmentation
Intercept	4.24	5.99	23.90	-261.06
Sale weight (kg)		.00		
Height (cm)		-.03		
Fat (somoscope, cm)	.34*	-.06		
Length (cm)		.02		4.39**
Depth (cm)		-.01		
Days (on feed)	.03		.80***	
Days squared (on feed)	.00			
Breed				
Angus	6.69***	5.76***	195.95***	266.12***
Hereford	6.76***	5.71***	166.28***	221.71***
Charolais	6.72***	5.67***	154.55***	195.91***
Treatment				
Grain	6.82***	5.77***	175.96***	223.83***
Silage	6.62***	5.65***	168.56***	232.01***
Residual mean square	4.26	.71	4110.95	7578.55
R ² x 100	13.08	3.14	23.48	10.46

*P<.05; **P<.01; ***P<.001.

fragmentation indices show grain-fed slightly lower in fresh fragmentation index value than for frozen. These data suggest that freezing has an effect upon residual fragmentation weights.

Data presented in Table 8 are regression analyses for the dependent variables Warner-Bratzler shear (WBS), tenderness rating, fresh and frozen fragmentation index with subjective live characteristics, sale weight and days on feed. Approximately 13% of the observed variation in WBS values could be accounted for by the independent variables in Table 8. Muscling score was the only variable indicating a significant effect on WBS values. This suggests that steers which were more heavily muscled initially produced less tender loin steaks.

Variability in tenderness rating was very low (C.D.=3.11) indicating no subjective animal score to be responsible for sensory tenderness rating (Table 8).

When frozen fragmentation was subjected to analyses with these same independent variables (Table 8), they accounted for 13.73% of the variation in frozen indices. Sale weight, days on feed treatment interaction and days squared treatment interaction showed a significant effect on frozen index (Table 8). These data indicate longer feeding periods regardless of ration produced progressively older steers with higher frozen indices suggesting less tender loin steaks.

In Table 9 are regression analyses for Warner-Bratzler shear (WBS), tenderness rating, fresh and frozen fragmentation index with carcass characteristics and days on feed. Marbling degree and days treatment interaction were more significant for WBS values (Table 9) and suggest that ribeyes containing more intramuscular fat were more tender than older steers which produced meat that was slightly less tender than those slaughtered at an earlier age.

Table 8--Partial regression coefficients and least squares means for equations predicting Warner-Bratzler shear, tenderness rating, fresh and frozen fragmentation index from subjective live characteristics, sale weight and days on feed

Model	Warner-Bratzler shear (1b)	Dependent variables		
		Tenderness rating	Fresh fragmentation	Frozen fragmentation
Intercept	4.18	4.77	-232.61	-3.89
Sale weight (kg)		.00	.27	.59*
Frame score ^a		.02	.35	
Muscle score ^a	.19*	-.04		
Fat (cm) ^b		.06	-6.08	
Days (on feed)	.02		2.43*	-1.05
Days squared (on feed)	.00		-.01	.00
Days x treatment				
Grain	.01		2.29	4.58*
Silage	.00		.00	.00
Days squared x treatment				
Grain			.01	-.01*
Silage			.00	.00
Breed				
Angus	6.77***	5.70***	198.12***	268.75***
Hereford	6.90***	5.65***	169.80***	223.33***
Charolais	6.50***	5.79***	148.01***	201.24***
Treatment				
Grain	6.80***	5.77***	176.22***	230.60***
Silage	6.64***	5.66***	167.74***	231.62***
Residual mean square	4.25	.70	4101.96	7474.56
R ²	13.23	3.11	25.94	13.73

^a15 point rating scale: 1 = -1; 15 = +5 (see Appendix J). ^bSubcutaneous fat subjectively estimated over 12th rib. *P<.05; ***P<.001.

Table 9--Partial regression coefficients and least square means for equations predicting Warner-Bratzler shear, tenderness rating, fresh and frozen fragmentation index from carcass characteristics and days on feed

Model	Warner-Bratzler shear (lb)	Dependent variables		
		Tenderness ratings	Fresh fragmentation	Frozen fragmentation
Intercept	10.71	5.32	69.62	263.41
Marbling degree ^a	-.03*	.01*	.42	
Lean texture ^b	-.17	.11*	-7.57*	-13.69*
Lean firmness ^b				9.65
Marbling distribution ^b		-.15**		
Carcass weight (kg)		.00		
Ribeye area (in ²)		-.14*		
Kidney, pelvic and heart fat (%)		.14		
Days (on feed)	-.01	-.01	.71***	-.14
Days squared (on feed)	.00	.00		
Days x treatment				
Grain	.10*	-.04*		.48
Silage	.00	.00		
Breed				
Angus	6.83***	5.70***	192.59***	261.39***
Hereford	6.72***	5.69***	168.47***	226.06***
Charolais	6.52***	5.74***	153.96***	208.45***
Treatment				
Grain	6.83***	5.72***	175.49***	232.29***
Silage	6.54***	5.70***	167.86***	231.65***
Residual mean square	4.25	.58	4055.95	7440.13
R ²	14.59	18.80	25.61	12.01

^aDevoid 10 = 1; Abundant 90 = 99.

^b8 point rating scales: 8 = very fine, firm, uniform; 1 = very coarse, soft, uneven.

*P<.05; **P<.01; ***P<.001.

Tenderness rating (C.D.=18.80; Table 9) was significantly related to marbling distribution, ribeye area, lean texture, days treatment interaction, marbling degree and days squared treatment interaction.

Fresh fragmentation index produced an r^2 of .26 (Table 9). Days on feed and lean texture showed significant effects with fresh fragmentation index (Table 9) and suggest as days on feed progressed the live animal became older inducing changes in muscle composition (Bailey, 1972; Cover et al., 1962).

Regression analyses for frozen fragmentation index with these same independent variables (Table 9) resulted in a coefficient of determination of 12.01. Correspondingly, frozen fragmentation was significant with lean texture suggesting that this subjective evaluation, as for fresh fragmentation index, is related to tenderness.

Least squares means presented in Table 7, 8 and 9 show Charolais' loin steaks to shear lower than Angus and Hereford steaks. Conversely, grain-fed steers produced higher values for shear than silage-fed steers. Taste panel ratings were about equal but indicated Charolais' loin steaks to be slightly more tender (Tables 7, 8 and 9). In addition, the panel found grain-fed steers to be slightly more tender than those fed silage. Indices for fresh and frozen fragmentation were larger for Angus, Hereford and Charolais, respectively. Grain-fed steers were indicated to yield heavier residues for the fresh fragmentation procedure and the frozen fragmentation samples tended to show similar results (Tables 7, 8 and 9).

Table 10 contains regression analyses for Warner-Bratzler shear (WBS) value and tenderness ratings with carcass characteristics, chemical fat, fresh fragmentation index and days on feed. Approximately 8.2%

Table 10. Partial regression coefficients and least squares means for equations predicting Warner-Bratzler shear and tenderness rating from carcass characteristics, chemical fat, fresh fragmentation index and days on feed

	Dependent variables	
	Warner-Bratzler shear (lb)	Tenderness rating
Intercept	9.09	4.97
Chemical fat (%WTB) ^a	-.07	.02
Carcass weight (kg)	.00	.00
Lean texture ^b	-.16	.04
Fresh fragmentation index	.00	.00
Days (on feed)	-.01*	.00
Breed		
Angus	6.54***	5.80***
Hereford	6.79***	5.71***
Charolais	6.49***	5.68***
Treatment		
Grain	6.68***	5.79***
Silage	6.53***	5.67***
Residual mean square	4.57	.71
R ²	8.17	2.19

^aWTB = whole tissue basis.

^b8 point rating scale: 8 = very fine; 1 = very coarse.

*P<.05; **P<.001.

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of the observed variation in WBS force value can be attributed to these independent variables (Table 10). Days on feed exhibited a low significant effect which suggest WBS values decreased slightly as days on feed increased (Table 10).

Regression of Warner-Bratzler shear values and tenderness ratings with carcass characteristics, frozen fragmentation index, and days on feed are presented in Table 11. Independent variables were responsible for 21% of the variation in WBS values. Frozen fragmentation index and days on feed were significant (Table 11) and suggest loin steaks from steers that were fed for longer periods to be slightly more tender and possess slightly higher frozen indices. Since these statements contradict each other, it follows that increased age within A maturity inducing compositional changes in muscle proteins is controlled by some phenomena. Perhaps cooking procedure where steaks are broiled at high temperature (approximately 250°C) for short times ($\bar{x}$ =32 minutes) contribute a tenderizing effect by solubilization of collagen. Animals fed for longer times would have higher intramuscular fat deposits in the proximity of connective tissue. The high heat-carrying capacity of the fat could induce greater degradation of the collagen (Blumer, 1963). Thus, older more highly finished steers within A maturity may be influenced in tenderness by a combination of factors.

A coefficient of determination of 10.31 was obtained for tenderness rating when regression analyses with carcass characteristics, frozen fragmentation index and days on feed were included in the model (Table 11). Carcass weight was the only carcass trait significantly related along with frozen fragmentation index. These data suggest that with increases in carcass weight taste panel members scored loin steaks slightly more tender. A similar trend (Table 11) was noted for frozen fragmentation index.

Table 11--Partial regression coefficients and least squares means for equations predicting Warner-Bratzler shear and tenderness rating from carcass characteristics, frozen fragmentation index and days on feed

Model	Dependent variables	
	Warner-Bratzler shear (lb)	Tenderness rating
Intercept	8.82	5.01
Carcass weight (lb)		.002*
Marbling degree ^a	-.02	
Frozen fragmentation index	.01***	-.002***
Days (on feed)	-.02***	
Days x treatment		
Grain	.01	
Silage	.00	
Breed		
Angus	6.40***	5.91***
Hereford	6.67***	5.77***
Charolais	6.80***	5.58***
Treatment		
Grain	6.56***	5.86***
Silage	6.68***	5.65***
Residual mean square	3.59	.62
R ² x 100	20.71	10.31

^aDevoid¹⁰ = 1; Abundant⁹⁰ = 99.

*P<.05; **P<.001.

CHAPTER V

CONCLUSIONS

Results of this study suggest the following conclusions: (a) Loin steaks from carcasses of steers representing three breeds (Angus, Hereford and Charolais) and two feeding regimes (grain and silage) were rated "slightly to moderately tender" for all breed and feeding regime groups when steers were fed to 12 mm fat thickness; (b) the following feeder calf scores, carcass traits, histological, physical and chemical traits generally were not significantly related to tenderness rating or Warner-Bratzler shear force value: feeder calf scores (sale weight, frame score, initial subjectively estimated fat (12th rib), length, depth and height); carcass traits (lean firmness, lean color, marbling texture, marbling variability, kidney, pelvic and heart fat (KPH), overall maturity and estimated ribeye fat (%); histological (sarcomere length); physical (water-holding capacity and fresh fragmentation index); and chemical (fat (%), WTB and MFB) and moisture (%); (c) the following feeder calf scores, carcass traits, histological, physical and chemical traits were generally significantly related to tenderness rating or Warner-Bratzler shear force value: feeder calf scores (initial fat (somoscope, 12th rib) and muscling score); carcass traits (carcass weight, marbling degree, lean texture, marbling distribution, and ribeye area); and physical (frozen fragmentation index); (d) frozen fragmentation index was linearly related to days on feed for grain-fed steers; (e) fresh fragmentation index was generally not related to days on feed, tenderness ratings or Warner-Bratzler shear values; (f) approximately 13% of the observed

variation in Warner-Bratzler shear force value or tenderness rating can be accounted for by use of objective and subjective (respectively) feeder calf measures or scores, (g) a multiple regression equation combining fixed environmental effects, marbling degree and frozen fragmentation index accounted for 20.71% of the observed variation in shear force values; (h) based on the data presented herein it appears that, regardless of breed, body type, muscling degree or feeding regime, steers fed to 12 mm fat thickness will produce cooked loin steaks possessing acceptable palatability.





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APPENDICES



APPENDIX A

Powdering Meat Samples

Materials

18 oz whirl pak bags
Permanent marker
Cutting board
Knife
Scalpel
2 asbestos or styrofoam containers (one large and one small)
Heavy gloves
Waring blender with metal blending jar and lid
Liquid nitrogen

Procedure

1. Trim meat sample removing all fat and epimyseal tissue.
2. Cut the trimmed muscle into 1 cm cubes
3. Fill a large asbestos container with liquid nitrogen and cover. Use this nitrogen for the following steps.
4. Cool blender lid and jar by pouring the liquid nitrogen so that it covers the blades.
5. Pour 4 to 6 cm of the liquid nitrogen in the smaller container and place 1 or 2 cubes in at a time. Wait until the nitrogen has finished bubbling and then transfer the sample to the blender immediately.
6. Blend until all sample is powdered. This is about 1-2 minutes.
7. Pour the powdered sample into the appropriately labeled whirl pak bag.
8. Store bag in a -2° freezer for subsequent use.

NOTE: Have adequate meat in a sample to cover the blades.
Keep blender jar cold at all times.
Do not clean with water if sample sticks to inside. Wipe out with a dry cloth.

APPENDIX B

Fat and Moisture Determination

Materials

Desiccator

Whatman No. 41 filter paper (15cm)

Stapler

Soxhlet apparatus: 71/60/29/42 body, 71/60 condenser and 29/42 1000 ml flask

Anhydrous ethyl ether

Disposable gloves

Hotplate (Chromalox by Edwin L. Wiegand Co., Pittsburgh, Pa.)

Mettler type H-6 analytical balance

Aluminum foil

Glass beads

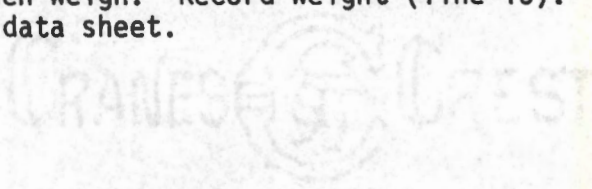
Procedure

Moisture

1. Make thimbles out of filter paper using the stapler and wear the disposable gloves while making or handling the thimbles.
2. Dry thimbles for approximately 2 hrs at 100°C under vacuum. Cool to room temperature in a desiccator.
3. For each powdered (see procedure for powdered meat samples) sample, remove a thimble from the desiccator and quickly weigh on the analytical balance. Record the sample number on the thimble in pencil and the sample number and thimble weight on the data sheet (lines 2 and 3).
4. Place approximately 2 grams of sample in the thimble and record weight on the data sheet (line 4).
5. Dry all samples prepared in this manner in a 100°C vacuum oven for approximately 5 hours.
6. Remove from the oven and cool the samples to room temperature in the desiccator. Reweigh and record the weight (line 6).
7. Calculate % moisture as indicated on the data sheet.

Fat

1. Pack thimbles from step 6 above in the soxhlet apparatus in one layer only with the stapled ends at the bottom. Fill excess space with aluminum foil.
2. Add enough ether to each flask to fill it slightly over one-half full (about 600 mls).
3. Assemble soxhlet according to Figure 1.
4. Turn hotplate to the low setting and make sure that the water is flowing properly through the condenser.
5. Extract for 8 hours from the time the thimbles are first covered by the ether.
6. After extraction has been completed disassemble the apparatus and return the ether to a container marked "used" ether.

7. Air dry under an evacuation hood for approximately 30 minutes until dry.
 8. Place the thimbles in a vacuum oven set at 100°C for approximately 4 hours.
 9. Cool thimbles in a desiccator and then weigh. Record weight (line 10).
 10. Calculate % fat as indicated on the data sheet.
- 

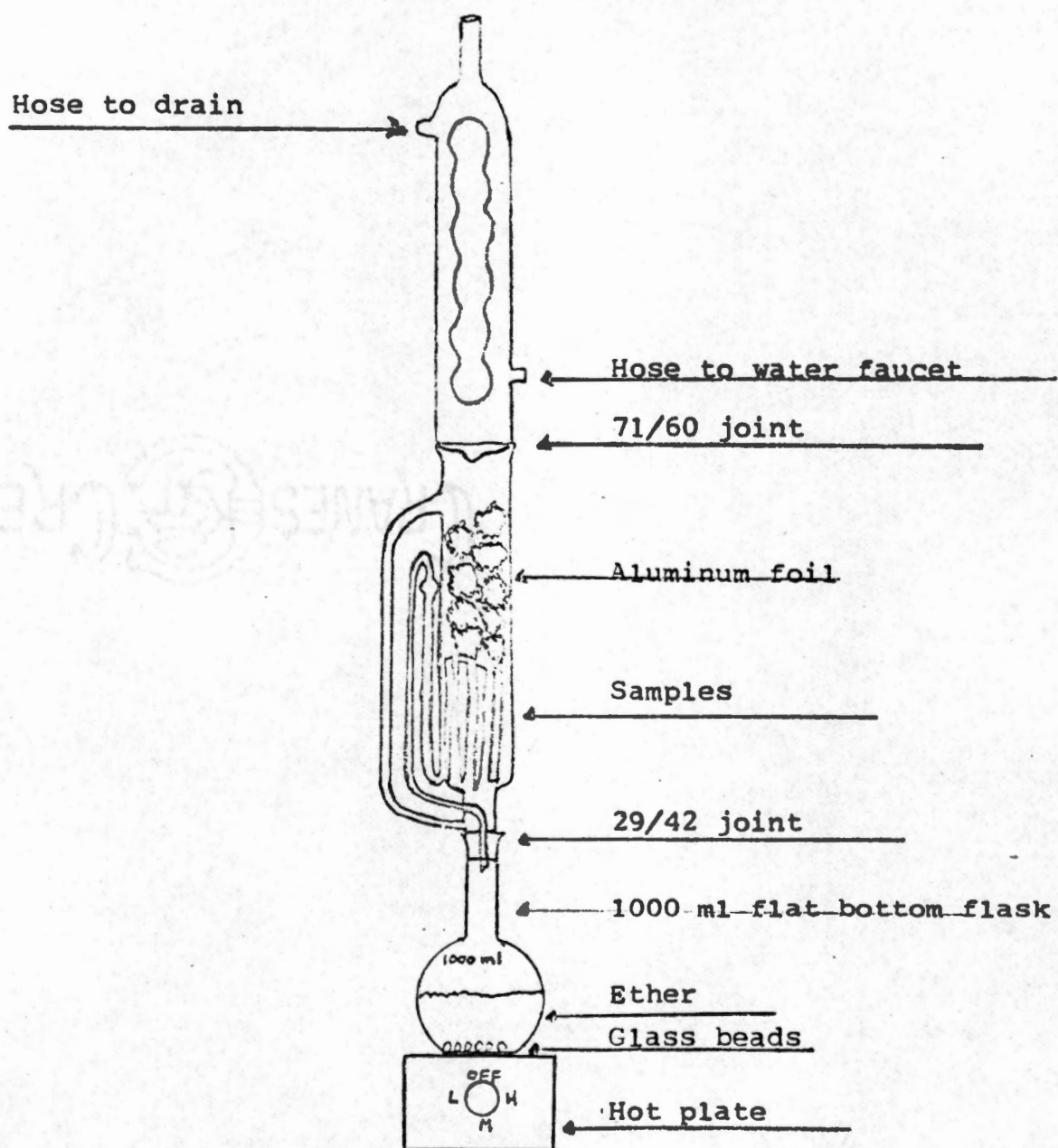


Figure A-1. Soxhlet assembly.

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DEPARTMENT OF FOOD TECHNOLOGY AND SCIENCE

Date _____

Tech. _____

Project _____

Repl. _____

Beaker									
1.	Thimble Number								
2.	Sample Number								
3.	Dry Thimble								
4.	Dry Thimble & Sample								
5.	Sample Wt. (Wet) (4-3)								
6.	Dry Thimble & Dry Sample								
7.	Dry Sample Wt. (6-3)								
8.	Moisture Wt. (5-7)								
9.	$\frac{8}{5}$ % Moisture								
10.	Dry Thimble & Dry, Extracted Sample								
11.	Extracted, Dry Sample (10-3)								
12.	Wt. Extracted Fat (7-11)								
13.	$\frac{12}{5}$ % Fat (Wet Basis)								
14.	$\frac{12}{7}$ % Fat (Dry Basis)								
15.	Avg. % Moisture								
16.	Avg. % Fat (Wet Basis)								
17.	Avg. % Fat (Dry Basis)								

APPENDIX C

Fragmentation

Materials

Knife

500 ml beaker

100 ml graduated cylinder

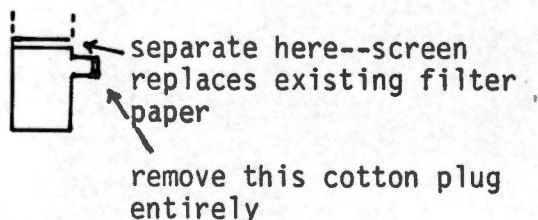
Mettler PL300 balance

0.02M KCl and 0.25M sucrose solution (made by mixing 5.96g KCl and 342.3g sucrose in 4 liters of water)

Plastic stirring rod

250 μ Nitex screen (cut 6cm x 7cm)

115 ml Nalgene filter unit (modified by separating top of unit to allow for screen insertion; see diagram)



Fisher scientific GRA universal timer model 171

Virtis "45" homogenizer equipped with macro stainless steel blades (16-108) set in a reverse position

15cm Whatman no. 3 filter paper

150 ml stainless steel homogenization cup

Procedure

1. Divide steak into cubes approximately 7 mm on a side, weight = 0.5g.
2. Randomly select cubes to make a 10g sample and place in a steel homogenization cup.
3. Add 50 ml of KCl-sucrose solution chilled at 4°C and allow to stand for 5 minutes.
4. Place flask of Virtis homogenizer with the dorsal blade within 1 mm of the surface of the solution.
5. Blend at full speed for 40 seconds. Preweigh Nitex screen and record weight.
6. Remove cup and pour homogenate into the Nalgene filter unit (as modified) and stir with the plastic stirring rod to facilitate filtering.
7. Blot briefly on Whatman no. 3 filter paper and allow to air dry for 10 minutes on Whatman no. 3 filter paper.
8. Weigh screen and residue. Final weight equals weight of screen and residue minus weight of screen.
9. Fragmentation index = residue weight (final weight) x 100.

APPENDIX D

Water Holding Capacity Determination

Materials

Carver laboratory press model C
Fisher scientific GRA universal timer model 171
Plexiglass plates
Whatman no. 2 filter paper
Desiccator containing a saturated solution of KCl
Mettler PL300 balance
No. 2 pencil
Compensating polar planimeter (K&E 62 0000)

Procedure

1. Place a sheet of Whatman no. 2 filter paper on the bottom plexiglass plate. Note: Filter paper is stored in desiccator.
2. Weigh a 500 mg sample of meat.
3. Cover with a second plexiglass plate.
4. Press on the Carver press for 5 minutes at a pressure of 4000 psi.
5. Prior to removal of the filter paper from the plexiglass plate, trace the meat film area.
6. Calculate the percent expressible juice using the Carpenter (1962) formula:

$$\% \text{ expressible juice} = 100 \left\{ \frac{\text{total juice area} - \text{meat film area}}{\text{total moisture (mg) in original muscle sample}} \right\} \times 44.07$$

APPENDIX E

Sarcomere Length Determination

Materials

Eyedropper

Osterizer Cycle Blend blender

Powerstat voltage regulator

Microscope with 15X ocular filar micrometer and 100X oil immersion objective
Formalin solution: 4% neutral formalin prepared by mixing together 10 mls of 40% formalin, 90 mls distilled water, 0.65 g Na_2HPO_4 and 0.49 NaH_2PO_4 .

Whirl pak bags

Glass slides, coverslips, melted paraffin and applicator stick.

Calibration of Micrometer

Equip the microscope with the 15X ocular micrometer and using the 100X oil immersion objective brings into focus the scale on a stage micrometer. Determine the number of ocular units to equal one unit on the stage micrometer. Each unit on the stage micrometer used here equals 0.1 mm. For example, it was determined that 0.4 mm on the stage micrometer represented 21 graduations on the scale within the ocular micrometer plus 17.5 graduations on the drum. Thus, $0.4 \text{ mm} - (21 \times 20) + 17.5$ graduations on the drum. Each graduation on the drum equals $\frac{0.4 \text{ mm}}{437.5}$ or $\frac{400\mu}{437.5}$ or 0.91μ . Each drum revolution equals $0.91\mu \times 20$ graduations or 18.20μ .

APPENDIX F

Cookery

Materials

Farberware electric "open hearth" broiler

Thermocouples

Mettler p2010 balance

Clock

Knife

Plexiglass sample sizer

Warner-Bratzler shearing apparatus

Procedure

1. Plug Farberware broilers into an electrical outlet and allow coals to heat until red. Have grills in low position.
2. Weigh steak.
3. Record time and place steak on grill. Cook to 35°C, moving steak frequently during this time. Note: Thermocouple is inserted laterally and inward to center.
4. Turn steak over when 35°C internal temperature has been reached and finish cooking steak in similar fashion until the internal temperature reaches 70°C. Remove and record time.
5. Weigh steak.
6. Cut and record degree of doneness.
7. Cube steak in plexiglass sizer for taste panel.
8. For shear force measurements, make four 1.3 cm cores and shear each one twice on a Warner-Bratzler shearing apparatus. Note: Make cores parallel to fibers and shear perpendicular to the fibers.

BROILING RECORD ()

Study:

Date:

Probe #					
Muscle & Cut					
Clock time: Off					
On					
Cooking Time					
Internal temp. On					
Off					
Wt. in gms:					
Frozen in paper					
Paper weight					
Frozen					
Raw					
Cooked					
Loss					
Percentage					
Served to taste panel as sample #					
Doneness of meat					
Shear (lbs)					
Mean					
Standard Deviation					

Scoring Sheet

Taste Panel and Cookery

<u>Juiciness</u>	<u>Tenderness</u>	<u>Connective Tissue Amount</u>
Extremely juicy (8)	Extremely tender (8)	None (1)
Very juicy (7)	Very tender (7)	Practically none (2)
Moderately juicy (6)	Moderately tender (6)	Traces (3)
Slightly juicy (5)	Slightly tender (5)	Slight (4)
slightly dry (4)	Slightly tough (4)	Moderate (5)
Moderately dry (3)	Moderately tough (3)	Slightly abundant (6)
Very dry (2)	Very tough (2)	Moderately abundant (7)
Extremely dry (1)	Extremely tough (1)	Abundant (8)

Flavor DescriptionFlavor Desirability

Extremely intense beef flavor (8)	Extremely desirable (8)
Very intense beef flavor (7)	Very desirable (7)
Moderately intense beef flavor (6)	Moderately desirable (6)
Slightly intense beef flavor (5)	Slightly desirable (5)
Slightly intense milky flavor (4)	Slightly undesirable (4)
Moderately intense milky flavor (3)	Moderately undesirable (3)
Very intense milky flavor (2)	Very undesirable (2)
Extremely intense milky flavor (1)	Extremely undesirable (1)

Overall DesirabilityDegree of Doneness

Extremely desirable (8)	Extremely well done (8)
Very desirable (7)	Very well done (7)
Moderately desirable (6)	Moderately well done (6)
Slightly desirable (5)	Done (5)
Slightly undesirable (4)	Slightly rare (4)
Moderately undesirable (3)	Moderately rare (3)
Very undesirable (2)	Very rare (2)
Extremely undesirable (1)	Extremely rare (1)

APPENDIX G

Codes for Various Evaluations

Lean color

8=light grayish red (pink)
 7=very light cherry red
 6=cherry red
 5=slightly dark red
 4=moderately dark red
 3=dark red
 2=very dark red
 1=black

Lean firmness

8=very firm
 7=firm
 6=moderately firm
 5=slightly firm
 4=slightly soft
 3=moderately soft
 2=soft
 1=very soft

Lean texture

8=very fine
 7=fine
 6=moderately fine
 5=slightly fine
 4=slightly coarse
 3=moderately coarse
 2=coarse
 1=very coarse

Marbling distribution

8=very uniform (even)
 7=uniform
 6=moderately uniform
 5=slightly uniform
 4=slightly uneven
 3=moderately uneven
 2=uneven
 1=very uneven

Marbling size variability

8=very uniform size
 7=uniform size
 6=moderately uniform size
 5=slightly uniform size
 4=slightly variable size
 3=variable size
 2=very variable size
 1=extremely variable size

Estimated tenderness

3=tender
 2=acceptable
 1=tough

Fat color

5=white; 1=dark yellow (Univ. of Ill.)

Conformation

Std⁻ = 6, P⁺ = 17

Relationship between marbling score and chemical fat (%WTB)

<u>Marbling score</u>	<u>Maturity score</u>	
	<u>A,B</u>	<u>C,D,E</u>
MD.AB.	10.32	9.21
SL.AB.	8.75	8.20
MD	7.02	7.07
MT	5.95	5.38
SM	5.21	4.30
SL	3.48	3.40
T	2.37	2.64
P.D.	1.37	1.18

APPENDIX H

Coding

U.S. Quality Grade

$$\begin{array}{l} \frac{\text{STD}^-}{00} = 6.01 \\ \text{to} \\ 33 = 6.33 \end{array}$$

$$\begin{array}{l} \frac{\text{GD}^-}{00} = 9.01 \\ \text{to} \\ 33 = 9.33 \end{array}$$

$$\begin{array}{l} \frac{\text{CH}^-}{00} = 12.01 \\ \text{to} \\ 33 = 12.33 \end{array}$$

$$\begin{array}{l} \frac{\text{P}^-}{00} = 15.01 \\ \text{to} \\ 33 = 15.33 \end{array}$$

$$\begin{array}{l} \frac{\text{STD}^0}{34} = 7.01 \\ \text{to} \\ 66 = 7.33 \end{array}$$

$$\begin{array}{l} \frac{\text{GD}^0}{34} = 10.01 \\ \text{to} \\ 66 = 10.33 \end{array}$$

$$\begin{array}{l} \frac{\text{CH}^0}{34} = 13.01 \\ \text{to} \\ 66 = 13.33 \end{array}$$

$$\begin{array}{l} \frac{\text{P}^0}{34} = 16.01 \\ \text{to} \\ 66 = 16.33 \end{array}$$

$$\begin{array}{l} \frac{\text{STD}^+}{67} = 8.01 \\ \text{to} \\ 99 = 8.33 \end{array}$$

$$\begin{array}{l} \frac{\text{GD}^+}{67} = 11.01 \\ \text{to} \\ 99 = 11.33 \end{array}$$

$$\begin{array}{l} \frac{\text{CH}^+}{67} = 14.01 \\ \text{to} \\ 99 = 14.33 \end{array}$$

$$\begin{array}{l} \frac{\text{P}^+}{67} = 17.01 \\ \text{to} \\ 99 = 17.33 \end{array}$$

Marbling Degree

$$\begin{array}{l} \text{D}^{10} = 1 \\ \text{PD}^{10} = 11 \\ \text{TR}^{10} = 21 \end{array}$$

$$\begin{array}{l} \text{SL}^{10} = 31 \\ \text{SM}^{10} = 41 \\ \text{MT}^{10} = 51 \end{array}$$

$$\begin{array}{l} \text{MD}^{10} = 61 \\ \text{SLAB}^{10} = 71 \\ \text{MDAB}^{10} = 81 \end{array}$$

$$\text{AB}^{10} = 91$$

Maturity

$$\begin{array}{l} \text{Cf}^{10} = 1 \\ \text{A}^{10} = 11 \\ \text{B}^{10} = 21 \end{array}$$

$$\begin{array}{l} \text{C}^{10} = 31 \\ \text{D}^{10} = 41 \\ \text{E}^{10} = 51 \end{array}$$

APPENDIX I

Data Form

Selector Name _____

Calf No.							
Meat Study No.							
Cell No.							
Overall Skeletal Maturity							
Lean Maturity							
Overall Maturity							
Lean Color							
Lean Firmness							
Lean Texture							
Marbling Texture							
Marbling Distribution							
Marbling Variability							
Marbling Degree							
Estimated Ribeye Fat %							
Final Quality							
Location							
Kill Date							
Selection Date							
Fat Color Score							
Estimated Tenderness							
Conformation							
Hot Carcass Weight							
Fat Thickness							
Adjusted Fat Thickness							
KPH %							
Ribeye Area							
Final Yield Grade							

APPENDIX J

Codes for Frame and Muscle Scores*

<u>Code</u>	<u>Score</u>	<u>Predicted Weight (lb) to Reach 12 mm Fat</u>
1	-1	...
2	1	800
3	+1	...
4	-2	...
5	2	900
6	+2	...
7	-3	...
8	3	1000
9	+3	...
10	-4	...
11	4	1100
12	+4	...
13	-5	...
14	5	1200
15	+5	...

*Shorter, blockier, flatter muscled, wastier, earlier maturing calves receive scores below 3 (average). Rangier, trimmer, thicker muscled, later maturing calves receive scores above 3 (average). Frame scores are a combination of length and height. For example: a score of 1 for height and 1 for length yields an overall frame score of 1. Similarly, if length = -1 and height = +1, then an overall frame score of 1 results. Muscling scores assigned to flat quartered, close fronted, narrow scoring calves are lower scores (1's and 2's) whereas very thick muscled, wider moving, grove-topped calves are higher score (4⁺ and 5's).

APPENDIX K

Table A1--Simple correlation coefficients for production measures

Measure	Depth	Length	Width	Fat Thickness	Muscle	Frame	Pcwt	Pdays
Height ^a	*** .57	*** .63	-.04	*** -.41	*** -.24	*** .78	.06	.01
Depth ^a		*** .52	.02	* -.17	*** -.38	*** .30	.06	.02
Length ^a			.09	*** -.36	-.08	*** .63	.10	.07
Width ^a				*** .27	*** .22	-.09	-.06	-.05
Fat Thickness ^b					-.01	*** -.48	-.11	-.06
Muscle ^c						.04	-.05	-.04
Frame ^c							.04	.01
Pcwt ^d								*** .99
Pdays ^e								--

^aInitial live animal measures (cm).

^bInitial fat thickness measured with somoscope (mm).

^cInitial subjective scores, 1 = -1, 15 = +5.

^dPredicted weight to reach 12 mm subcutaneous fat.

^ePredicted days to reach 12 mm subcutaneous fat. *P<.05; **P<.01; ***P<.001.

Table A2--Partial regression coefficients and least squares means^a

Source	Carcass Weight			Days to 12 mm Fat		
	1	2	3	1	2	3
Purchase wt	*** .51	*** .66	*** .51	-.07	.15	.01
Height						
High Ration		*** 11.62	*** 9.20		*** 5.83	*** 3.99
Med Ration		*** 6.05	* 3.39		.77	-.89
Fat		*** -34.51	*** -30.06		*** -17.56	*** -13.26
A			*** -17.69			
H			*** -51.28			
C			*** -27.62			
AH			* -5.35			
Depth		*** -8.28			*** -5.16	-2.75
Breed						
A	*** 587		*** 594	*** 202		*** 205
H	569		577	198		203
C	687		644	261		249
AH	586		595	195		199
Ration						
High	602	600	599	*** 190	*** 189	*** 191
Med	613	608	606	238	235	237

Table A2--continued

Source	Carcass Weight			Days to 12 mm Fat		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Year						
1975	*616	604	605	***228	***222	***225
1976	599	604	601	200	202	203
R ²	.37	.46	.56	.45	.45	.54

^aThese are data collected from previous years by the Department of Animal Science, The University of Tennessee, and were used in derivation of prediction equations for steers utilized in this study.

VITA

The author was born December 14, 1954 at Quonset Point, Rhode Island. He was the second son of Mr. and Mrs. Frank Hutsell, Jr. Due to his father's military occupation, his family relocated residences several times during his early childhood. Upon his father's retirement the family established permanent residence in Athens, Tennessee, where they maintain a farm and approximately 100 head of beef cattle.

He attended McMinn County High School and graduated in 1973 with honors in his class. He entered Tennessee Technological University that same year and graduated with a Bachelor of Science degree in animal science in August 1977. In the fall of 1977 he entered the University of Tennessee and completed his graduate studies in June 1979.

He is an alumni of Alpha Gamma Sigma fraternity (professional agricultural fraternity), a member of the American Meat Science Association, the American Society of Animal Science, Gamma Sigma Delta (agricultural honor society), The Institute of Food Technologists and Phi Tau Sigma (food technology honor society).