Bulletin 420
June 1967

EFFECT OF AGE OF BEEF FEMALES ON CARCASS COMPOSITION, MEAT CHARACTERISTICS, AND PALATABILITY

by C. B. Ramsey, J. W. Cole, and R. L. Sliger

AGRL. EXP. STA
APR - 11968
UNIV. OF TENN

The University of Tennessee
Agricultural Experiment Station
John A. Ewing, Director
Knoxville

SUMMARY

The effects of age on carcass composition, meat characteristics, and palatability were studied on 138 Angus and Hereford heifers and cows from three Tennessee Agricultural research centers. Age of animal ranged from 3 to 211 months and live weights from 165 to 1,300 pounds. Animal age was coded on 6-month intervals and least squares analyses were used to determine age effects.

The youngest calves received the highest carcass conformation grades. Animals under 36 months of age usually received higher grades than older ones.

Carcass maturity scores, determined by Federal graders, were significantly related ($r = 0.81$) to actual animal age. This indicated that the graders generally were able to recognize maturity differences in the carcasses.

Average marbling score increased until the animals were 30 months old. No significant differences were found among groups over 30 months of age.

Fat thickness over the ribeye tended to increase until the cows were over 101 months old. The increase after 24 months of age was much less than that in younger heifers.

Percent separable muscle in the 9-10-11 rib section tended to decrease with age, but the muscle content means of those groups over 6 months of age were not significantly different. Separable fat was inversely related to muscle. Percent separable bone did not vary significantly with age.

Calves had the lowest intramuscular fat content, and this varied little with increasing age after the cows reached 36 months of age. Crude protein content was not significantly influenced by age.

Roasts from calves 3 to 11 months old were most tender. However, these scores were significantly different from only the 12 to 17, 72 to 77, and over 95 months age groups. Age had less influence on tenderness after 12 months. Age was more highly associated with tenderness scores ($r = 0.46$) than with juiciness ($r = 0.17$) and flavor ($r = 0.11$) scores. Holding measures of fatness constant changed the relationship between age and tenderness very little. On a fat constant basis, the association between age and either juiciness or flavor score was near zero. Thus, age had little or no effect on meat juiciness and flavor but significantly influenced tenderness.

CONTENTS

	Page
Summary	2
Experimental Procedure	4
Results and Discussion	7
Relationships Among Traits	19
Literature Cited	24

EFFECT OF AGE OF BEEF FEMALES ON CARCASS COMPOSITION, MEAT CHARACTERISTICS, AND PALATABILITY*

by
C. B. Ramsey, J. W. Cole, and R. L. Sliger**

Increased interest has been shown in factors which affect beef carcass composition and beef palatability. The usefulness of maturity levels in carcass grading has been questioned, and recent modifications have been made in the maturity grading standards. If maturity or a comparable measure of the physiological age of beef carcasses is to retain a prominent position in beef grading, a thorough investigation of the influence of animal age on carcass composition, meat characteristics, and palatability is needed. The objectives of this reasearch were to determine the effects of chronological age of beef females on carcass composition, muscle and fat characteristics, and meat palatability.

Experimental Procedure

This investigation was conducted over a 4-year period from 1961 to 1965. One hundred thirty-eight females, varying in chronological age from 3 to 211 months and in slaughter weight from 165 to 1,300 pounds, were selected from three of the beef cattle breeding herds of the University of Tennessee (Table 1). Angus were selected at Ames Plantation and the Plateau Experiment Station, and Herefords were selected from the Alcoa herd of the Main Experiment Station at Knoxville.

Selection Criteria. The general criteria used in selecting the females under 2 years of age were low daily gains before weaning, questionable inheritance, poor performance of dam and/or sire, undesirable conformation, or failure to exhibit a normal estrus

*Gratitude is expressed to Dr. Bernadine H. Meyer and her staff of the Food Science and Institution Management Department for conducting the cooking and sensory tests.

**Assistant Professor, Associate Professor, and former Graduate Student, respectively, Animal Husbandry-Veterinary Science Department.

Table 1. Source, breed, age, and weight of experimental animals

Herd Location	Breed	No. of animals	Slaughter age, mo. Mean	Slaughter age, mo. Range	Slaughter wt., lb. Mean	Slaughter wt., lb. Range
Ames Plantation, Grand Junction	Angus	50	51	5-114	832	250-1145
Plateau Experiment Station, Crossville	Angus	45	48	3-211	806	165-1280
Main Experiment Station, Knoxville	Hereford	43	51	5-135	911	250-1300

cycle. The older animals generally were removed from the breeding herd because of failure to conceive, low milk production, unacceptable performance of progeny, or unfavorable pedigree. These are the usual reasons for removing a female from a breeding herd. However, many animals used in the study met none of these criteria and were selected because of the needs of the study.

Average Daily Gain. Daily gain for the heifers slaughtered at pre-weaning ages represents the average daily gain from birth to slaughter. Average daily gain from birth to weaning was used for all animals slaughtered at post-weaning ages. However, these data were not available for all animals.

Slaughter. The females were slaughtered during all seasons of the year. Pre-weaning groups were sent to slaughter directly off their dams. The post-weaning groups received a normal maintenance ration before slaughter. Those from the Ames Plantation herd were slaughtered at the Memphis Packing Plant, Memphis, Tennessee. The Plateau and Knoxville Station cattle were slaughtered at the East Tennessee Packing Company, Knoxville, Tennessee.

Carcass Data. Each female was weighed individually at the stations and at the packing plant. Hot carcass weight was obtained after washing but before shrouding. After a 48-hour chill, a federal grader determined maturity score, marbling score, conformation grade, and carcass grade.

One measurement, to the nearest 0.05 inch, of fat thickness was made over the **longissimus dorsi (l. dorsi)** muscle between the 12th and 13th ribs at a point three-fourths the length of the muscle from the chine end as described by Ramsey **et al.** (1962). Area of the **l. dorsi** (ribeye) muscle was measured to the nearest 0.1 square inch with a compensating polar planimeter.

Carcass length was measured to the nearest 0.1 inch on the right side from the anterior edge of the first rib to the anterior edge of the aitch bone.

Wholesale Rib. The wholesale rib, containing ribs 6 through 12, was cut from the left side of each carcass and shipped to the Meat Laboratory for analysis. It was weighed to the nearest 0.1 pound and separated into 6-7-8, 9-10-11, and 12 rib sections.

The 6-7-8 rib section was boned, wrapped, and frozen for cooking tests. The 9-10-11 rib section was physically separated into muscle, fat, and bone. The components were weighed individually to the nearest 0.1 pound, and each weight was expressed as a percent of the original 9-10-11 rib section weight. After all intermuscular fat was removed from the **l. dorsi** muscle of the 9-10-11 rib section, specific gravity of this muscle section was determined as described by Backus (1958). The **l. dorsi** muscle was then ground three times in a grinder with a 3/32-inch plate and mixed thoroughly after each grinding. A representative sample was placed in a closed glass container and frozen for chemical analyses later. The remainder of the ground **l. dorsi** muscle was combined with the other muscle and fat tissue of the 9-10-11 rib section and ground to a paste consistency. A representative sample was frozen for later analyses.

Approximately one-half hour after cutting, the 9-10-11 rib section was subjectively evaluated for muscle and fat color. Scores for muscle color were: 5 = pale, 4 = light red, 3 = slightly dark red, 2 = dark red, and 1 = very dark red. Fat color was scored with Munsell Color Paddles.

The 12th rib section was used in studies not reported herein.

Chemical Analyses. The ground samples of **l. dorsi** muscle and 9-10-11 rib section muscle plus fat were thawed, and samples of about 2 grams were analyzed in triplicate for moisture, ether extract, and crude protein. A.O.A.C. (1960) procedures were used with the exception that protein was determined by the Kjeldahl method.

Cooking. Boneless roasts from the 6-7-8 rib section were cooked in groups of four after each roast was randomly assigned within slaughter date to a cooking group. On the day before cooking, the roasts were removed from the freezer, thawed 7 hours at room temperature, and refrigerated overnight. They were wiped

with a damp cloth, weighed to the nearest gram, and placed with the fat side up on a rack in an uncovered roasting pan. The roasts were cooked to an internal temperature of 155° F. in a Despatch oven which was preheated to 325° F. Weights to determine cooking losses were taken after the roasts had cooled about 10 minutes.

Palatability Evaluation. Two cores, 1 inch in diameter, were removed from the **l. dorsi** muscle of each cooked roast, cooled one hour at room temperature, and sheared three times each with a Warner-Bratzler shear machine. The six shear values were averaged. An experienced six-member sensory panel scored 3/8-inch cross sectional slices of the **l. dorsi** muscle for tenderness, juiciness, and flavor. Each panel member received a sample from the same location within each muscle. Scoring was on a 9-point hedonic scale with 9 = excellent and 1 = poor. The six scores for each attribute were averaged.

Statistical Analyses. The data were analyzed by the method of least squares (Harvey, 1960). The chronological age of each animal was coded on a 6-month-interval basis, and a constant was fitted for age effects. Thus, age was treated as a discrete variable or a variable of classification. When age effects were significant, means were tested with Duncan's (1955) Multiple Range Test as extended by Kramer (1957). Simple correlation coefficients were calculated on a within-location basis.

Results and Discussion

Source of Animals. Approximately one-third of the beef females in this study were obtained from each of the three experiment station herds (Table 1). It would have been desirable to have had animals with common ancestry, similar treatment, and similar feeding. However, females from breeding herds are the only immediately available source of a large number of bovine animals varying widely in age.

The Angus and Herefords were similar in average slaughter age, but the Herefords were heavier than the Angus.

Slaughter Age and Weight. The females were segregated into age groups at 6-month intervals to determine the effects of slaughter age on several characteristics (Table 2). There were two exceptions to this classification. The 11 calves in the youngest age

Table 2. Number of animals per age group and means for slaughter age and weight

Age group, mo.	No. of animals	Slaughter age mean, mo.	Slaughter wt. mean, lb.
3-5	11	4.5	212
6-11	4	7.3	504
12-17	7	14.6	528
18-23	6	19.5	656
24-29	13	27.3	765
30-35	12	31.6	825
36-41	19	39.9	869
42-47	7	43.0	939
48-53	13	51.8	962
54-59	2	55.0	949
60-65	5	63.4	1062
66-71	5	67.8	1000
72-77	7	75.0	1003
78-83	4	78.5	926
84-89	5	87.2	1143
90-95	2	91.0	1036
96-101	7	98.6	887
102+	9	136.7	998

group (3 to 5 months) had an age range of only 3 months because no calves under 3 months of age were slaughtered. Also, the oldest age group contained 9 cows which ranged in age from 102 to 211 months and averaged 136.7 months.

The number of animals within age groups varied from 2 to 19. Because of this wide range, a least squares analysis was used in order to obtain estimates of the effects of slaughter age on most slaughter and carcass characteristics.

Slaughter weight tended to increase until the females were 60 to 65 months of age. Those over 96 months of age tended to have lower average weights than those between 60 and 95 months of age.

Carcass Grade Factors. Carcass conformation grades, indicators of carcass shape, blockiness, and thickness of muscling, were not analyzed statistically because these data were incomplete. Observation of the existing data (Table 3) revealed that the youngest calves were given the highest average conformation grade (average Good-). Those under 36 months of age tended to receive higher average grades than older ones. No apparent trend was noted in those older than 36 months. Cows older than 102 months received

Table 3. Least square means for the effects of age on carcass characteristics

Age group, mo.	Conformation grade[g, h]	Maturity score[i]	Marbling score[j]	Carcass grade[h]	Fat thickness, in.	Ribeye area, [g] sq. in.
3-5	16.9	0.9 a	1.9 a	16.3 a	0.05 a	—
6-11	—	1.2 a,b	3.5 a,b	17.5 a	0.08 a,b	—
12-17	15.0	1.8 b	2.8 a,b	14.4 a,b	0.16 a,b	7.8
18-23	—	2.1 b	3.7 b	15.8 a	0.13 a,b	9.0
24-29	15.0	3.0 c	4.5 b,c	15.8 a	0.31 a,b,c	9.4
30-35	16.4	3.5 c,d	5.2 b,c,d	15.9 a	0.30 a,b,c	9.8
36-41	11.1	4.0 d,e	5.0 b,c,d	12.8 b,c	0.31 a,b,c	9.6
42-47	—	4.2 d,e	4.8 b,c,d	13.0 b,c	0.39 b,c,d	9.5
48-53	11.1	5.4 f	5.0 b,c,d	9.9 c,d	0.35 b,c,d	10.4
54-59	9.5	5.2 e,f	5.2 b,c,d	9.2 c,d	0.34 a,b,c,d	—
60-65	9.5	6.4 f	4.6 b,c,d	9.0 d	0.41 b,c,d	11.3
66-71	12.0	5.8 f	4.8 b,c,d	9.7 c,d	0.45 b,c,d	10.1
72-77	10.2	6.6 f	5.4 b,c,d	9.1 d	0.47 b,c,d	10.0
78-83	14.0	6.7 f	4.8 b,c,d	9.6 c,d	0.48 c,d	10.0
84-89	9.5	6.5 f	6.8 d	10.0 c,d	0.51 c,d	10.8
90-95	—	6.7 f	5.7 b,c,d	11.2 b,c,d	0.47 b,c,d	10.8
96-101	15.0	6.3 f	5.8 c,d	9.8 c,d	0.56 d	11.4
102+	8.5	6.7 f	4.5 b,c	8.1 d	0.37 b,c,d	10.4

a, b, c, d, e, f. Means with common superscripts are not significantly different. All others differ significantly ($P < .05$).
g. Unadjusted averages. These data were not analyzed statistically.
h. 8 = Average Utility; 17 = average Good.
i. 1 = Veal or Calf; 2 = A; 6 = E.
j. 1 = Devoid; 6 = Modest.

the lowest average carcass conformation grade (average Utility), indicating that these carcasses were more angular and less thick and meaty than carcasses of the younger animals. At a young age these females would have received higher average conformation grades.

The federal graders used degree of ossification, size and shape of the bones and cartilages, and the color and texture of the muscles to determine carcass maturity score. Least squares means for the effects of chronological age of the animals on maturity score show that the graders generally were able to recognize the maturity (or physiological age) differences in these cattle which varied widely in age.

Carcasses from calves under 12 months of age were given a maturity score of Veal or Calf. These were scored significantly ($P<.05$) less mature than animals older than 23 months. Carcasses of females between 1 and 2 years of age received a mean

maturity score of A; those between 2 and 3 received B; those between 3 and 4 received C; those between 4 and 5 received D; and those 5 years and older received E or E+.

Mean maturity scores tended to increase until the females were 48 to 53 months old. Differences among age groups older than 48 months were not significant. Assuming that the above-mentioned bone and muscle characteristics indicate physiological maturity, these data indicate that physiological maturity probably was reached when the females were about 4 years old.

Although the mean maturity scores showed an increase with chronological age, considerable overlapping was found among ages. For example, two animals from the same herd were both 44 months old when slaughtered. However, they received maturity scores of C and F, respectively. On the other hand, two were given the same maturity score (B), but their ages were 39 and 16 months, respectively.

Marbling score, a subjective measure of intramuscular fat, tended to increase until the animals were 30 months old. The youngest group had a mean score of 1.9 (practically devoid), which was significantly lower than for all groups over 17 months of age. No significant differences were found between age groups over 29 months of age. Also, the two groups between 12 and 23 months of age differed significantly from only two older groups.

Comparisons of marbling scores by herd locations revealed that Ames Plantation Angus averaged 5.1; Crossville Angus, 5.2; and Knoxville Herefords, 3.6. This probably indicates a breed difference and substantiates other reports (Barbella **et al.**, 1939; Carpenter **et al.**, 1955; Cartwright **et al.**, 1957; and Cole **et al.**, 1964).

USDA carcass grades ranged from high Cutter to average Prime with an overall mean of high Commercial. Angus graded about two-thirds of a grade higher than Herefords. This probably was the result of more marbling within the ribeye muscle of the Angus.

Females under 36 months of age graded significantly higher—with the exception of the 12-17 month group—than those over 36 months of age. However, mean grades of age groups under 36 months did not differ significantly nor did those of groups older than 48 months. Cows in the oldest group graded lowest (average

Utility). The USDA beef grade standards in effect during this study offer a possible explanation for this pattern. Carcasses from animals under 36 months of age generally were not graded lower than low Standard, whereas those from cows over 48 months old (commonly called "hard-boned") generally were not graded above high Commercial.

Fat Thickness and Ribeye Area. Fat thickness over the ribeye muscle at the 12th rib ranged from 0.05 to 1.1 inches and showed a general tendency to increase with age of animal until the cows were over 101 months old (Table 3). Calves under 12 months of age had a very thin layer of fat. However, the thickness doubled in the next 6 months and reached an average of 0.3 inch when the heifers were about 24 months old. Only slight increases with age were found after the animals were over 2 years old.

Ribeye area was not determined in the heifers under 12 months of age because of the softness of the muscle and lack of external fat. These two factors allowed distortion of the muscle and gross changes in muscle area after ribbing. Observation of the available averages revealed that ribeye area increased until the animals were about 3 years old and changed little with age thereafter. Since ribeye area usually is highly influenced by body or carcass weight (Cole **et al.**, 1960a), the practical value of this information is questionable.

Measures of Carcass Composition. Weights of the wholesale rib, containing the 6th through 12th ribs, ranged from 2.9 to 42.3 pounds. The more rapid increase in weight occurred between 3 and 35 months of age (Table 4) Differences in weights of wholesale ribs from animals older than 42 months were not significant ($P>.05$).

Malkus and Henrickson (1964) found an increased percentage of the beef carcass in the wholesale rib with increasing age of Hereford heifers 9, 12, 15, and 18 months of age. These cattle were full-fed a fattening ration after 9 months of age. The results of the present study generally agree with those reported on the full-fed cattle.

The 9-10-11 rib section was used to estimate carcass composition. Hankins and Howe (1946) found that the composition of this cut indicated carcass composition. The weight of this section tended to increase with age until the animals were about 53 months

Table 4. Least square means for the effects of age on carcass composition

Age group	Wholesale rib wt.	Wt.	9-10-11 Rib section			Boneless 9-10-11 rib section		
			Separable muscle	Separable fat	Separable bone	Moisture	Ether extract	Crude protein
mo.	lb.	lb.	%	%	%	%	%	%
3-5	4.2 a	1.7 a	65.9	14.8 a	19.3 a	67.6 c	10.6	19.3 c
6-11	8.2 a,b	3.4 a,b	56.9 a	24.6 a,b	19.0 a	58.9 a	22.2 a	16.8 a,b
12-17	13.0 b,c	5.1 b,c	55.2 a	26.0 a,b	18.5 a	55.3 a	28.4 a	15.7 a,b
18-23	17.0 c,d	6.2 c,d	54.6 a	27.4 b	18.0 a	54.5 a	27.7 a	16.4 a,b
24-29	19.4 d	7.1 d,e	51.0 a	30.3 b	18.5 a	50.9 a,b	32.1 a,b	15.5 a,b
30-35	21.6 d,e,f	8.1 e,f	52.9 a	29.8 b	17.2 a	51.4 a,b	31.4 a,b	15.1 a,b
36-41	21.1 d,e	8.1 e,f	52.1 a	29.1 b	18.5 a	51.5 a,b	31.0 a,b	16.3 b
42-47	22.4 d,e,f	8.6 e,f	50.9 a	32.4 b	16.3 a	47.8 a,b	36.1 a,b	15.0 b
48-53	24.3 e,f	8.9 f	50.3 a	30.2 b	19.3 a	49.1 a,b	34.1 a,b	14.8 b
54-59	22.2 d,e,f	7.9 d,e,f	53.2 a	27.3 a,b	19.5 a	53.1 a,b	29.6 a,b	15.1 a,b
60-65	28.4 f	10.8 f	50.0 a	33.1 b	16.9 a	48.5 a,b	34.9 a,b	14.8 b
66-71	24.8 e,f	9.5 f	48.9 a	33.4 b	17.7 a	48.4 a,b	35.8 a,b	14.3 b
72-77	25.6 f	9.9 f	50.0 a	32.3 b	17.7 a	47.0 a,b	37.5 a,b	14.8 b
78-83	22.5 d,e,f	8.7 e,f	50.7 a	32.3 b	16.9 a	47.8 a,b	36.6 a,b	14.5 b
84-89	28.8 f	11.5 f	46.2 a	39.6 b	14.2 a	43.1 b	42.9 b	12.9 b
90-95	28.7 f	10.1 f	45.8 a	38.6 b	15.6 a	44.8 a,b	40.2 a,b	14.2 b
96-101	27.3 f	10.4 f	47.2 a	38.5 b	14.1 a	43.7 b	42.3 b	13.1 b
102+	25.8 f	9.4 f	50.6 a	30.1 b	19.2 a	51.1 a,b	32.3 a,b	14.9 b

a, b, c, d, e, f. Means with common superscripts are not significantly different. All others differ significantly ($P < .05$).

old. However, differences in weight of this cut in animals older than 30 months were not significant.

Percent separable muscle of the 9-10-11 rib section is indicative ($r = 0.75$) of carcass separable muscle (Cole **et al.**, 1960a). Heifers from 3 to 5 months old had a significantly ($P<.05$) greater percent separable muscle in the 9-10-11 rib section than older females. Although the separable muscle content of females older than 6 months was not significantly different from that of younger age groups, there was a trend toward a decrease in the observed muscle means with advancing age. This decrease was from a mean of 56.9% in 6- to 11-month-old heifers to 45.8% in 90- to 95-month-old cows. Those cows over 96 months of age had higher muscle percentages than those between 84 and 95 months of age. These muscle percentages show a general inverse relation to fat thickness (Table 3) and to separable fat percentages of the 9-10-11 rib section (Table 4).

Separable fat means ranged from 14.8% in the 3- to 5-month-old heifers to 39.6% in the 84- to 89-month-old cows. However, because of the variation within age groups, differences among all groups younger than 18 months or older than 6 months were not significantly different ($P>.05$).

Separable bone percentages differed less among age groups than either muscle or fat. There was a slight tendency toward a decrease in bone percentage with increasing age to 101 months. However, there were no significant differences among age groups. Cows over 102 months of age had almost the same bone percentage as the calves under 12 months of age (19.2 vs. 19.3 and 19.0). Thus, it appears that the oldest cows had reached a declining physiological state in which they lost fat from their bodies. A loss of fat tends to increase muscle and bone percentages.

Chemical analyses were performed on the separable muscle plus separable fat of the 9-10-11 rib section. Moisture and crude protein tended to decrease and ether extractable components tended to increase with advancing age of animal up to 101 months (Table 4). However, few of these differences were statistically significant because of the large variation within age groups. Malkus and Henrickson (1964) found similar age effects with heifers 9 to 18 months old. Separable muscle and moisture, separable fat and ether extract, and separable bone and crude protein showed similar patterns of variation among age groups. Thus, it appears that either

physical separations or chemical analyses can be used to determine the influence of animal age on carcass composition.

Composition of the L. Dorsi Muscle. The **l. dorsi** in the 9-10-11 rib section was excised, weighed, and its specific gravity determined (Table 5). The heifers under 12 months of age had the lightest **l. dorsi** muscles ($P<.05$). The weight increased most rapidly between 3 and 35 months of age and fluctuated thereafter, suggesting that the **l. dorsi** is an early maturing muscle. The heavier weight of the muscle in some age groups, such as the one 84 to 89 months old, probably was due to a higher intramuscular fat content rather than to greater muscle development.

Specific gravity of the **l. dorsi** of the 9-10-11 rib section failed to reveal a definite trend with respect to animal age. Cole **et al.** (1960b) found high associations between specific gravity and marbling score ($r = -.78$) and percent ether extractable components ($r = -.81$). In view of this strong correlation between marbling score and specific gravity, the variation in specific gravity observed here is not surprising because marbling score, as

Table 5. Least square means for the effects of age on composition of the Longissimus Dorsi **muscle of the 9-10-11 rib section**

Age group, mo.	LONGISSIMUS DORSI muscle of 9-10-11 rib section				
	Wt., lb.	Specific gravity	Moisture %	Ether extract %	Crude protein %
3-5	0.50 a	1.0667 a	76.5 a	0.4 a	20.8 a
6-11	0.71 a	1.0658 a,b	76.2 a,b	1.3 a,b	19.8 a
12-17	1.14 b	1.0595 b,c	74.7 a,b,c	2.5 a,b,c	21.7 a
18-23	1.33 b,c	1.0650 a,b	74.5 a,b,c,d	2.3 a,b,c	20.7 a
24-29	1.42 b,c,d	1.0638 a,b	73.4 c,d,e	3.4 a,b,c	21.0 a
30-35	1.66 d,e	1.0604 b, c	73.4 c,d,e	3.7 a,b,c	21.0 a
36-41	1.59 c,d,e	1.0610 b,c	73.2 c,d,e	4.4 c,d	21.1 a
42-47	1.69 d,e	1.0633 a,b,c	72.4 c,d,e	4.7 c,d	21.1 a
48-53	1.81 d,e,f	1.0606 b,c	72.9 c,d,e	4.6 c,d	20.7 a
54-59	1.49 b,c,d,e	1.0615 a,b,c	73.6 a,b,c,d,e	3.8 a,b,c,d	21.0 a
60-65	2.13 f,g	1.0616 a,b,c	73.5 b,c,d,e	4.3 b,c,d	20.9 a
66-71	1.85 d,e,f,g	1.0561 b,c	72.0 d,e	4.9 c,d	21.7 a
72-77	1.94 e,f,g	1.0601 b,c	72.1 d,e	4.8 c,d	21.4 a
78-83	1.75 d,e,f	1.0621 a,b,c	72.4 c,d,e	4.2 b,c,d	21.7 a
84-89	2.18 g	1.0551 c	70.0 e	7.6 d	21.1 a
90-95	1.88 d,e,f,g	1.0587 b,c	70.8 e	6.3 c,d	21.7 a
96-101	2.01 f,g	1.0570 b,c	70.7 e	6.7 d	21.4 a
102+	1.79 d,e,f	1.0615 a,b,c	73.4 c,d,e	4.0 b,c,d	20.6 a

a, b, c, d, e, f, g. Means with common superscripts are not significantly different. All others differ significantly ($P<.05$).

has already been pointed out, was quite variable in the present study.

The Herefords had a higher average specific gravity (1.0641) than the Angus (1.0599). This indication of a higher percent intramuscular fat in the Angus substantiates the marbling score differences between breeds previously mentioned.

Chemical analyses of the excised **l. dorsi** revealed that percent moisture tended to decrease with advancing age to 101 months and then increased (Table 5). The mean value for 3- to 5-month-old calves was 76.5%, and this decreased to 70.0% for 84- to 89-month-old cows. The cows over 102 months old had values comparable to 2-year-old animals (73.4%).

The mean for ether extractable components of the **l. dorsi** increased from 0.4% in 3- to 5-month old calves to 4.7% in 42- to 47-month-old calves. However, no definite trend was noted in older cows. Cows which were 84 to 101 months old had the highest values. The oldest cows had a mean percentage comparable to that of much younger animals. Tuma **et al.** (1962) likewise found no significant effect of age on ether extract content of **l. dorsi** muscle from 18, 42, and 90-month-old Hereford females. These data indicate that young animals should be selected if a low percent intramuscular fat is desired, and that the average intramuscular fat content varies little after cows reach 36 months of age.

Crude protein content of the **l. dorsi** was not significantly ($P>.05$) influenced by animal age. No trend was noted with changes in age. These results agree with the report by Tuma **et. al.** (1962). Thus, moisture tends to decrease, ether extract tends to increase, and crude protein tends to remain constant as animal age increases. The greatest changes occur before the animals are 2 years old.

Muscle and Fat Color. Slaughter age significantly influenced the color of the **l. dorsi.** Color was subjectively evaluated on the cross-section between the 11th and 12th ribs. Muscle from calves under 12 months of age was scored significantly lighter red than that of older animals (Table 6). The muscle tended to become darker in color until the animals were about 24 months old. After this age there was only a slight tendency for the muscle color to darken with increasing age. Within the age range that most steers and heifers are sold (12 to 24 months), differences in muscle color

Table 6. Least square means for the effects of age on muscle and fat color, cooking losses, and meat palatability

Age group, mo.	Muscle color[g]	Fat color[h]	Cooking losses			Shear score, lb.	Sensory panel scores		
			Drip %	Evaporation %	Total %		Tenderness	Juiciness	Flavor
3-5	4.6 a	1.5 a	2.8 a	16.1 a	18.9 a	13.8 a	8.6 a	6.2	6.6 a
6-11	4.6 a	2.3 a,b	3.3 a,b	14.3 a	17.6 a	14.1 a,b	8.4 a,b	6.4	7.1 a,b
12-17	3.9 b	2.4 a,b	3.2 a	14.4 a	17.6 a	19.2 c,d	6.5 c,d	6.9 a	6.9 a,b
18-23	3.6 b,c	2.7 a,b	4.5 a,b,c	14.4 a	18.9 a	17.6 a,b,c,d	6.9 c,d	7.0 a,b	7.2 a,b
24-29	3.0 c	3.5 b,c	4.5 a,b,c	13.9 a	18.4 a	17.3 a,b,c,d	6.8 c,d	7.0 a,b	7.3 a,b
30-35	3.1 c	3.5 b,c	4.5 a,b,c	15.4 a	19.9 a,b	16.1 a,b,c	7.5 b,c	7.3 c	7.5 b
36-41	2.9 c,d	4.4 c,d,e	4.3 a,b,c	15.3 a	19.6 a,b	16.8 a,b,c,d	7.0 c,d	7.2 b,c	7.2 a,b
42-47	3.3 b,c	4.2 c,d	5.8 c	15.3 a	21.2 a,b	17.8 a,b,c,d	6.5 c,d	6.9 a	7.4 b
48-53	2.9 c,d	4.6 d,e	5.2 b,c	16.8 a	22.0 b	17.5 a,b,c,d	6.3 c,d	7.0 a,b	7.2 a,b
54-59	2.0 d	6.7 f	4.3 a,b,c	17.3 a	21.7 a,b	17.9 a,b,c,d	6.1 c,d	7.4 c	7.5 b
60-65	2.6 c,d	5.4 d,e,f	7.0 c	16.4 a	23.4 b	18.4 b,c,d	6.4 c,d	7.1 a,b,c	7.3 a,b
66-71	2.9 c,d	4.7 d,e,f	6.1 c	15.1 a	21.2 a,b	17.4 a,b,c,d	6.7 c,d	6.9 a	7.4 b
72-77	2.6 c,d	5.2 d,e,f	6.4 c	16.3 a	22.6 b	19.8 d	5.8 d	7.1 a,b,c	7.3 a,b
78-83	2.7 c,d	4.4 c,d,e	5.1 a,b,c	16.2 a	21.3 a,b	17.7 a,b,c,d	6.8 c,d	7.0 a,b	7.3 a,b
84-89	2.6 c,d	5.1 d,e,f	6.9 c	14.7 a	21.6 a,b	17.4 a,b,c,d	5.8 d	6.8 a	7.1 a,b
90-95	2.6 c,d	6.6 e,f	7.3 c	16.1 a	23.4 b	16.6 a,b,c,d	5.3 d	7.2 b,c	7.3 a,b
96-101	2.3 d	4.8 d,e,f	6.9 c	16.2 a	23.1 b	18.7 c,d	6.2 c,d	7.3 c	7.3 a,b
102+	2.4 d	6.6 e,f	5.1 a,b,c	17.1 a	22.2 b	19.8 d	5.8 d	6.9 a	7.1 a,b

a, b, c, d, e, f. Means with common superscripts are not significantly different. All others differ significantly ($P < .05$).

g. 4 = Slightly dark red; 2 = Dark red.

h. A higher value indicates a more intense yellow color.

were not significant. Likewise, calves under 12 months of age did not differ significantly in muscle color. These results substantiate the work of Helser (1930), who reported that muscle from calves was a lighter red color than that from older cattle; Simone **et al.** (1959), who found that muscle from 30-month-old steers was darker than muscle from 18-month-old steers; and Tuma **et al.** (1963), who observed that muscle tissue became darker with advancing animal age.

Fat color was scored with the aid of Munsell Color Paddles which gave a higher score to a more intense yellow color. The younger animals tended to receive lower scores, indicating whiter fat. Fat color tended to become more yellow until the animals were about 4 years old. After this age no trend was noted. Although the mean color score increased from 1.5 in 3- to 5-month old calves to 2.7 in 18- to 23-month-old heifers, these differences were not significant ($P>.05$). Likewise, differences between animals from 6 to 35 months old were not significant. Thus, in animals between 6 and 36 months of age, fat color would not be expected to significantly influence consumer selection of beef.

Cooking Losses. Animal age influenced percent drip loss of the roasted boneless 6-7-8 rib sections. The youngest calves had the lowest mean loss (2.8%); but, due to the large amount of variation within groups, differences between groups 3 to 41 months of age were not significant ($P>.05$). Likewise, groups over 18 months of age did not differ significantly. The increases in drip losses generally paralleled increases in separable fat of the 9-10-11 rib section. This suggests that fatter roasts can be expected to have greater drip losses during cooking. These findings support the work of Jacobson and Fenton (1956), who found that drip losses from roasts of cattle 32, 48, 64, and 80 weeks of age tended to increase with animal age.

Evaporative losses were not significantly influenced by animal age. No definite trend with respect to age was noted. This agrees with the report of Jacobson and Fenton (1956).

Total cooking losses (drip plus evaporation) tended to be higher in roasts from females over about 48 months of age than for younger ones. However, few differences among age groups were statistically significant ($P<.05$). The major difference was that those under 30 months of age had lower losses than those 48 to 53, 60 to 65, 72 to 77, and over 90 months of age. Total losses

ranged from 17.6% in roasts from animals 6 to 17 months old to 23.4% in roasts from two groups over 60 months old. These results contradict the work of Nelson **et al.** (1930), who found that roasts from feeder calves had greater cooking losses than those from 2-year-old cattle. Since evaporative losses did not differ significantly with age, most of the variation in total losses could be attributed to differences in drip losses.

Shear Scores. Two 1-inch diameter cores from the **l. dorsi** muscle from the cooked 6-7-8 rib roast were sheared three times each with the Warner-Bratzler shear machine. These six objective measures of tenderness were averaged (Table 6).

Roasts from the calves 3 to 11 months of age had the lowest (most tender) shear scores (13.8 and 14.1 lb.). However, these scores were significantly lower than those from only the groups 12 to 17, 72 to 77, and over 95 months old. Likewise, with one exception those animals over 11 months of age did not significantly differ in shear score. The exception was that those 30 to 35 months old had a lower shear score (16.1 lb.) than those between the ages of 72 and 77 months and those over 101 months (19.8 lb.). A notable result is the higher shear score (19.2 lb.) of the 12- to 17-month-old group as compared to younger groups. This age group would include a large portion of cattle slaughtered. Cattle in this age range may be in a state in which their muscle is less tender than that of younger or slightly older cattle.

Tenderness, Juiciness, and Flavor Scores. Sensory panel scores for tenderness of the **l. dorsi** of the 6-7-8 rib roast showed a pattern similar to that for shear scores. Calves from 3 to 5 months of age were scored more tender ($P<.05$) than all older groups except those 6 to 11 months old. Scores from all groups older than 11 months did not significantly differ with the exception of the 30- to 35-month-old group which differed from the groups 72 to 77, 84 to 95, and over 101 months old.

Tenderness scores, like shear scores, showed a significant decrease between the ages of 6 to 11 and 12 to 17 months (8.4 vs 6.5). Hiner and Hankins (1950) likewise found that meat from veal calves was more tender than that of 8-month-old steer calves; steers 14 months of age were even less tender. The 14-month-old steers and 37-month-old heifers did not significantly differ in tenderness. However, Dunsing (1959) found that steaks from 18-month-old steers were preferred on tenderness by a wide margin

over those from 30-month-old steers. Likewise, Tuma **et al.** (1962) reported that steaks from 18-month-old heifers were much more tender than those from 42- or 90-month-old cows. Simone **et al.** (1959) found that a sensory panel preferred the tenderness of meat from 18-month-old steers over 30-month-old steers. Although differences in the meat cut studied and in feeding regime and environment may account for some of the discrepancies among the above reports, further study is needed to determine the effect of chronological age on meat tenderness.

The mean juiciness score (6.2) was significantly lowest for the roasts from the 3- to 5-month-old calves. Also, the score (6.4) for those 6 to 11 months old was significantly lower than for the older animals. Although significant differences were found between some groups over 12 months of age, no trend was noted with advancing age. These group means ranged from 6.8 to 7.4, both of which would be in the "Good" range of ratings by the panel. These results tend to substantiate those of Simone **et al.** (1959) and Tuma **et al.** (1962).

The mean flavor score (6.6) for the youngest calves was lowest but differed significantly only from four other groups which were between 30 and 71 months old. Differences among groups over 6 months old were not significant. Thus, after the animals reached 6 months of age, chronological age had little influence on flavor of the meat. The panel apparently was not very critical of either the blandness associated with the meat of the young calves or the more intense flavor of older animals. All age groups received mean scores near a "Good" rating. Tuma **et al.** (1962) and Tuma **et al.** (1963) obtained similar results.

Relationships Among Traits

Simple correlation coefficients between selected characteristics were calculated on a within-breed-and-herd location basis. The data from only 59 animals were used in calculating the coefficients involving average daily gain (A.D.G.), carcass weight, ribeye area, and carcass length. All other correlations involved variables measured on all 138 animals.

Average Daily Gain. The A.D.G. to weaning or slaughter (in the case of the young calves slaughtered before weaning) was significantly ($P<.01$) associated with slaughter age ($r = 0.35$),

maturity score, slaughter weight, and hot carcass weight (Table 7). This indicates that the animals which had higher average daily gains before weaning tended to stay in the herds longer and thus become older and heavier. Because of this they tended to grade lower in the carcass, have larger ribeye areas, be longer-bodied, have heavier 9-10-11 rib sections, and be darker in color of both muscle and fat.

The association between A.D.G. and carcass length ($r = 0.55$) was studied further. Calculation of partial correlation coefficients revealed that, on a slaughter age constant basis, carcass length, and A.D.G. still were positively associated ($r_{12\cdot3} = 0.45$). Thus, the longer-bodied animals tended to gain faster to weaning. On a carcass weight constant basis, the association between carcass length and A.D.G. was lower ($r_{12\cdot3} = 0.27$).

A.D.G. and sensory panel tenderness score showed a low negative association ($r = -.14$). On a slaughter age constant basis, the association approached zero ($r_{12\cdot3} = 0.04$). This indicates that A.D.G. and meat tenderness apparently are independent variables.

Slaughter Age and Meat Palatability. Variation in age of animal accounted for 66% of the variation in carcass maturity score, indicating that the Federal graders did a fairly good job of segregating the carcasses according to chronological age. The older animals tended to be heavier at slaughter ($r = 0.60$), have heavier carcasses ($r = 0.76$), have more marbling ($r = 0.31$), grade lower ($r = -.69$), have larger **l. dorsi** areas (0.56), be fatter ($r = 0.42$), and be less tender by both shear score ($r = 0.34$) and panel tenderness ($r = -.46$). Slaughter age and juiciness and flavor scores showed little association ($r = 0.17$ and 0.11, respectively).

The association between slaughter age and tenderness score was changed little when either fat thickness, percent ether extract in the 9-10-11 rib **l. dorsi**, or marbling score was held constant ($r_{12\cdot3} = -.41$, $-.42$, and $-.47$, respectively). Thus, fat content of the carcass and of the muscles themselves had little or no effect on tenderness of the muscle. This also was true when shear score was used as a measure of tenderness. Shear score and panel tenderness score were significantly related ($r = -.78$).

Different relationships were found among slaughter age, panel juiciness or flavor scores, and measures of fatness. When the above-mentioned measures of fat content were held constant, the

Table 7. Simple correlation coefficients between selected characteristics[a]

Characteristic	A.D.G.[b]	Slaughter age	Maturity score	Slaughter wt.	Carcass wt.[b]	Marbling score	Carcass grade	Ribeye area[b]	Fat thickness	Shear score	Sensory panel score		
											Tenderness	Juiciness	Flavor
Maturity score	0.50**	0.81**											
Slaughter wt.	0.52**	0.60**	0.75**										
Carcass wt.[b]	0.50**	0.76**	0.76**	0.97**									
Marbling score	0.13	0.31**	0.43**	0.58**	0.50**								
Carcass grade	−.38**	−.69**	−.82**	−.48**	−.42**	−.03							
Ribeye area[b]	0.35**	0.56**	0.52**	0.68**	0.75**	0.34**	−.24**						
Fat thickness	0.25	0.42**	0.48**	0.56**	0.77**	0.60**	−.19*	0.49**					
Shear score	0.04	0.34**	0.33**	0.29**	0.01	−.01	−.34**	0.07	0.10				
Sensory panel score													
Tenderness	−.14	−.46**	−.49**	−.49**	−.22	−.13	0.46**	−.16	−.23**	−.78**			
Juiciness	−.19	0.17*	0.27**	0.33**	0.06	0.48**	−.11	−.01	0.28**	0.04	−.02		
Flavor	0.06	0.11	0.23**	0.34**	0.35**	0.36**	−.05	0.22	0.31**	−.18*	0.17*	0.40**	
Carcass length[b]	0.55**	0.78**	0.82**	0.94**	0.87**	0.35**	0.56**	0.57**	0.59**	0.11	−.38**	0.06	0.45**
9-10-11 Rib section													
Wt.	0.40**	0.61**	0.72**	0.87**	0.95**	0.65**	−.39**	0.74**	0.76**	0.26**	−.45**	0.35**	0.34**
% Separable muscle	0.17	−.28**	−.35**	−.48**	−.26**	−.49**	0.10	−.08	−.60**	−.21*	0.27**	−.30**	−.26**
% Separable fat	0.18	0.32**	0.38**	0.57**	0.60**	0.61**	−.05	0.42**	0.73**	0.11	−.19*	0.32**	0.26**
% Separable bone	−.02	−.11	−.13	−.31**	−.53**	−.46**	−.14	−.46**	−.62**	0.09	−.02	−.10	−.15
Boneless 9-10-11 rib section													
% Moisture	−.25	−.38**	−.48**	−.68**	−.72**	−.66**	0.15	−.47**	−.78**	−.16	0.29**	−.33**	−.32**
% Ether extract	0.19	0.38**	0.48**	0.67**	0.70**	0.66**	−.15	0.44**	0.78**	0.16	−.29**	0.32**	0.32**
% Protein	−.07	−.33**	−.44**	−.56**	−.67**	−.56**	0.14	−.40**	−.69**	−.10	0.19*	−.28**	−.30**
9-10-11 Rib **L.dorsi**													
% Moisture	−.09	−.40**	−.47**	−.61**	−.66**	−.79**	0.12	−.49**	−.74**	−.09	0.28**	−.34**	−.28**
% Ether extract	0.17	0.36**	0.44**	0.59**	0.62**	0.85**	−.08	0.50**	0.69**	0.06	−.23**	0.37**	0.28**
% Protein	−.28*	0.03	0.03	0.03	−.30*	−.21*	−.13	−.25	0.01	0.20*	−.22**	−.23**	−.13
Specific gravity	−.01	−.21*	−.31**	−.36**	−.44**	−.56**	0.11	−.48**	−.44**	0.06	0.11	−.29**	−.05
Drip loss	0.35**	0.41**	0.50**	0.57**	0.79**	0.55**	−.18*	0.61**	0.70**	0.12	−.25**	0.18*	0.22**
Evaporation loss	0.20	0.25**	0.25**	0.02	0.12	−.23**	−.39**	0.16	−.24**	0.17*	−.17*	−.15	−.06
Total loss	0.40**	0.50**	0.56**	0.42**	0.66**	0.20*	−.46**	0.56**	0.29**	0.22*	−.31**	0.01	0.11
Muscle color	−.33*	−.60**	−.69**	−.63**	−.43**	−.28**	0.58**	−.22	−.33**	−.38**	0.51**	−.24**	−.19*
Fat color	0.37**	0.71**	0.73**	0.61**	0.42**	0.30**	−.64**	0.29*	0.26**	0.37**	−.55**	0.19*	0.11

**P .01.

*P .05.

a. Calculated on a within-location basis.

b. N 59; N = 138 for all other variables.

association between slaughter age and either juiciness or flavor score was near zero. Thus, age of animal had little or no effect on meat juiciness and flavor.

Marbling score, fat thickness, and percent ether extract in the 9-10-11 rib **l. dorsi** muscle were positively associated ($P<.01$) with both juiciness and flavor of the meat (Table 7). These simple correlation coefficients ranged from 0.28 to 0.48. Holding slaughter age constant changed the magnitude of these coefficients little, if any. Thus, slaughter age appeared to significantly influence meat tenderness but had little or no effect on juiciness and flavor. On the other hand, marbling score and related measures of fatness appeared to significantly influence juiciness and flavor but had little or no effect on tenderness.

Other factors which were significantly related to meat tenderness were color of muscle and fat. Darker-colored muscle and more yellow fat tended to be associated with lower tenderness of muscle as measured by both shear value and panel tenderness score. The relationship between muscle color and panel tenderness score was studied on a constant slaughter-age basis because of the known association between age and muscle color. The correlation between muscle color and panel tenderness score ($r = 0.51$) was reduced when slaughter age was held constant ($r_{12.3} = 0.34$); but muscle color still accounted for about 12% of the variation in tenderness score. Color of fat had a similar relationship to muscle tenderness on an age constant basis.

Slaughter age was significantly associated also with measures of carcass composition. Increases in animal age tended to be accompanied by more fat, less muscle, less moisture, and less protein in the carcass. Cooking losses increased and muscle and fat color both became more intense with increasing age.

Maturity Score. The maturity score given by the Federal grader had close to the same relationship to the various other characteristics as did actual chronological age. Thus, the two measures of maturity could be used interchangeably in most instances. Notable differences were that maturity score was more highly related to slaughter weight ($r = 0.75$), marbling score ($r = 0.43$), and carcass grade ($r = -.82$) than was slaughter age.

Slaughter and Carcass Weight. Live weight at slaughter was most highly related to hot carcass weight ($r = 0.97$), carcass

length ($r = 0.94$), weight of the 9-10-11 rib section ($r = 0.87$), and ribeye area ($r = 0.68$). Measures of muscle were negatively associated and measures of fat positively associated with weight. Most correlation coefficients involving carcass weight were of like sign and of similar magnitude as those involving slaughter weight.

Marbling Score. A subjective measure of intramuscular fat content, marbling score, was highly associated with fat thickness ($r = 0.60$), percent separable fat in the 9-10-11 rib section ($r = 0.61$), percent ether extract in the boneless 9-10-11 rib section ($r = 0.66$), percent ether extract in the **l. dorsi** ($r = 0.85$), specific gravity ($r = -.56$), and drip loss ($r = 0.55$) of the 6-7-8 rib roast. Marbling score had little influence on carcass grade ($r = -.03$). However, on a slaughter age constant basis, marbling score had a positive effect on carcass grade ($r_{12\text{-}3} = 0.27$).

Fat Thickness Over the Ribeye. Fat thickness had the highest association of any variable studied with percent separable muscle ($r = -.60$), separable fat ($r = 0.73$), and separable bone ($r = -.62$) of the 9-10-11 rib section, and the proximate composition of the boneless 9-10-11 rib section. Fat thickness likewise was highly associated with the moisture ($r = -.74$) and ether extract ($r = 0.69$) contents of the **l. dorsi** muscle and the percent drip loss ($r = 0.70$) of the 6-7-8 rib roast.

LITERATURE CITED

A.O.A.C. **Official Methods of Analysis (9th ed.).** Association of Official Agricultural Chemists, Washington, D. C., 1960.

Backus, William R. "Specific Gravity of the **Longissimus Dorsi** Muscle From the 9-10-11 Rib Section as an Objective Measure of Beef Carcass Eating Quality." M.S. Thesis, University of Tennessee, 1958.

Barbella, N. J., B. Tanner, and T. G. Johnson. "Relationships of Flavor and Juiciness of Beef to Fatness and Other Factors." Proceedings of American Society of Animal Production 32:320, 1939.

Carpenter, J. W., A. Z. Palmer, W. G. Kirk, F. M. Peacock, and M. Koger. "Slaughter and Carcass Differences Between Brahman and Brahman-Shorthorn Crossbred Steers." Journal of Animal Science 14:1228, 1955 (abstract).

Cartwright, T. C., S. Cover, and O. D. Butler. "The Relationship of Inheritance to Tenderness of the Meat of Yearling Steers." Journal of Animal Science 16:1026, 1957 (abstract).

Cole, J. W., L. E. Orme, and C. M. Kincaid. "Relationship of Loin Eye Area, Separable Lean of Various Beef Cuts and Carcass Measurements to Total Carcass Lean in Beef." Journal of Animal Science 19:89, 1960a.

Cole, J. W., W. R. Backus, and L. E. Orme. "Specific Gravity as an Objective Measure of Beef Eating Quality." Journal of Animal Science 19:167, 1960b.

Cole, J. W., C. B. Ramsey, and C. S. Hobbs. "Effects of Type and Breed of British, Zebu, and Dairy Cattle on Production, Carcass Composition, and Palatability." Journal of Dairy Science XLVII:10:1138, 1964.

Duncan, D. B. "Multiple Range and Multiple F Test." Biometrics 11:1, 1955.

Dunsing, M. "Visual and Eating Preferences of Consumer Household Panel for Beef from Animals of Different Age." Journal of Food Technology 13:332, 1959.

Hankins, O. G. and P. E. Howe. **Estimation of the Composition of Beef Carcasses and Cuts. U.S.D.A. Technical Bulletin 926, 1946.**

Harvey, Walter R. **Least-Squares Analysis of Data with Unequal Sub-class Numbers.** U.S.D.A. ARS-20-8, 1960.

Helser, M. D. **Influence of the Animal's Age Upon the Quality and Palatability of Beef. I. Carcass Yields and Quality of Meat Cuts.** Iowa Agric. Expt. Station Bulletin 272:303, 1930.

Hiner, R. L. and O. G. Hankins. "The Tenderness of Beef in Relation to Different Muscles and Age in the Animal." Journal of Animal Science 9:347, 1950.

Jacobson, Marion and Faith Fenton. "Effects of Three Levels of Nutrition and Age of Animal on the Quality of Beef." Food Research 21:436, 1956.

Kramer, C. Y. "Extension of Multiple Range Tests to Group Correlated Adjusted Means." Biometrics 13:13, 1957.

Malkus, L. A. and R. L. Henrickson. **Growth and Development of Beef Heifers from Weaning to 18 Months of Age.** Oklahoma Agric. Expt. Station Misc. Publ. 74:18, 1964.

Nelson, Mabel, Belle Lowe, and M. D. Helser. **Influence of the Animal's Age Upon the Quality and Palatability of Beef. II. The Roast Beef, Preparation, Quality, and Palatability.** Iowa Agric. Expt. Station Bulletin 272:311, 1930.

Ramsey, C. B., J. W. Cole, and C. S. Hobbs. "Relation of Beef Carcass Grades, Proposed Yield Grades, and Fat Thickness to Separable Lean, Fat, and Bone." Journal of Animal Science 21:193, 1962.

Simone, M., F. Carroll, and C. O. Chichester. "Differences in Eating Quality Factors of Beef from 18- and 30-month Steers." Journal of Food Technology 13:337, 1959.

Tuma, H. J., R. L. Henrickson, G. V. Odell, and D. F. Stephens. "Variation in the Physical and Chemical Characteristics of the **Longissimus Dorsi** Muscle from Animals Differing in Age." Journal of Animal Science 22:354, 1963.

Tuma, H. J., R. L. Henrickson, D. F. Stephens, and Ruby Moore. "Influence of Marbling and Animal Age on Factors Associated with Beef Quality." Journal of Animal Science 21:848, 1962.

THE UNIVERSITY OF TENNESSEE
AGRICULTURAL EXPERIMENT STATION
KNOXVILLE, TENNESSEE

Agricultural Committee

Board of Trustees

Andrew D. Holt, President
Clyde M. York, Chairman
Ben Douglass, Harry W. Laughlin, Wassell Randolph
W. F. Moss, Commissioner of Agriculture

STATION OFFICERS

Administration

Andrew D. Holt, President
Webster Pendergrass, Dean of Agriculture
E. J. Chapman, Assistant Dean
J. A. Ewing, Director
Eric Winters, Associate Director
J. L. Anderson, Budget Officer

Department Heads

S. E. Bennett, Agricultural Biology
T. J. Whatley, Agricultural Economics and Rural Sociology
J. J. McDow, Agricultural Engineering
Harold J. Smith, Agriculture, University of Tennessee at Martin
L. F. Seatz, Agronomy
C. S. Hobbs, Animal Husbandry-Veterinary Science
Ruth L. Highberger, Child Development and Family Relationships
J. T. Miles, Dairying
Grayce E. Goertz, Foods and Institution Management
M. R. Johnston, Food Technology
J. W. Barrett, Forestry
Myra L. Bishop, Home Management, Equipment, and Family Economics
B. S. Pickett, Horticulture
R. L. Hamilton, Information
Mary R. Gram, Nutrition
K. L. Hertel, Physics
O. E. Goff, Poultry
Anna J. Treece, Textiles and Clothing

University of Tennessee Agricultural Research Units

Main Station, Knoxville, J. N. Odom, Superintendent of Farms
University of Tennessee-Atomic Energy Commission Agricultural Research Laboratory, Oak Ridge, N. S. Hall, Laboratory Director

Branch Stations

Dairy Experiment Station, Lewisburg, J. R. Owen, Superintendent
Highland Rim Experiment Station, Springfield, L. M. Safley, Superintendent
Middle Tennessee Experiment Station, Spring Hill, J. W. High, Jr., Superintendent
Plateau Experiment Station, Crossville, J. A. Odom, Superintendent
Tobacco Experiment Station, Greeneville, J. H. Felts, Superintendent
West Tennessee Experiment Station, Jackson, B. P. Hazlewood, Superintendent

Field Stations

Ames Plantation, Grand Junction, James M. Bryan, Manager
Cumberland Plateau Forestry Field Station, Wartburg, J. S. Kring, Manager
Friendship Forestry Field Station, Chattanooga
Highland Rim Forestry Field Station, Tullahoma, P. J. Huffman, Jr., Manager
Milan Field Station, Milan, T. C. McCutchen, Manager
Oak Ridge Forest and Arboretum, Oak Ridge, R. D. MacDonald, Manager

(3M/1-68)