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To the Graduate Council:

I am submitting herewith a thesis written by Robert Lee Sliger entitled "Influence of Age of Beef Females on Carcass Composition, Meat Characteristics and Palatability." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

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

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
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Master of Science

by
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CHAPTER I

INTRODUCTION

While many nations of the world are striving to provide a more adequate quantity of red meat, the meat consumers of the United States are more concerned with the composition and palatability of a presently abundant meat supply. Although American consumers currently enjoy an abundant supply of wholesome, palatable beef, the explosive expansion of the population is retiring increasing quantities of land from forage and cereal grain production annually. Thus the availability of cereal grain for the improvement of beef quality may be an item of concern for future generations.

Meat scientists have the challenge of maintaining or improving beef palatability while production techniques are constantly being modified in accordance with research findings. This enormous challenge can best be met with a more thorough knowledge of the factors influencing or associated with carcass composition, meat characteristics and palatability.

In the past decade, the meat industry and meat researchers have shown much interest in beef carcass composition and the numerous factors which are influential in beef palatability variations. In more recent years, the usefulness of maturity levels in beef carcass grading has been questioned and modifications in the grading standards have been installed regarding carcass maturity. There is increasing evidence

that the role of beef carcass maturity, or the chronological age of animals at slaughter, is over-emphasized in beef quality evaluation. If maturity or a comparable measure of the physiological age of beef carcasses is to retain a prominent position in beef carcass grading standards, a thorough investigation of the influence of animal age on carcass composition, meat characteristics and palatability is unquestionably warranted.

The primary objectives of the research reported herein were:

1. To determine the effect of chronological age of beef females at slaughter on subsequent measures of beef carcass composition.
2. To investigate the effect of slaughter age on meat characteristics as measured by cooking tests and subjective evaluations.
3. To evaluate the influence of animal age on meat palatability using as criteria mechanical shear tests and sensory panel scores for tenderness, juiciness and flavor.

CHAPTER II

REVIEW OF LITERATURE

Research work pertaining to the influence of the slaughter age of an animal on subsequent beef carcass characteristics is more limited than research endeavors concerning other variables thought to influence beef carcass characteristics. Only in recent years has the slaughter age of animals and/or beef carcass maturity been receiving appropriate attention as a source of variation in carcass composition, meat characteristics and palatability.

I. CARCASS COMPOSITION

Jacobson and Fenton (1956a) found a decrease in the water content of bovine muscle with increasing animal age when comparing animals 32, 48, 64 and 80 weeks of age. Fat content increased in animals that had been receiving either medium or high levels of total digestible nutrients prior to slaughter. Results of this study indicated that the nitrogen content of either moist or dry, fat-free bovine muscle tissue increased with increasing animal age.

Simone et al. (1959) reported that 30-month-old steers had a slightly higher per cent fat, as ether extract of the 12th rib cut, than did 18-month-old steers. However, more variation in fat content was found between Good and Choice steers within a particular age group. This difference was more pronounced in the 18-month-old steers.

Tuma et al. (1962b) found that moisture, ash, protein and fat content of the longissimus dorsi muscle did not differ significantly among age groups. This study included 24 Hereford females, 18, 42 and 90 months of age, with similar breeding and management backgrounds.

Goll et al. (1963) studied the composition of the biceps femoris muscle of 11 cattle of differing genetic and nutritional backgrounds. Four age groups were represented in the study. The results indicated that muscle tissue from veal calves possessed significantly less protein and more moisture than muscle tissue from either 15-month-old steers, 5-year-old cows or 10-year-old cows. However, muscle tissue from 10-year-old cows had significantly more moisture than either 15-month-old steers or the 5-year-old cows. Significantly less fat was found in the muscle tissue of veal calves and 10-year-old cows than 15-month-old steers and 5-year-old cows, but there was no significant difference in the fat content between either veal calves and 10-year-old cows or between 15-month-old steers and 5-year-old cows. The per cent of fresh biceps femoris tissue not accounted for by protein, fat and moisture was not significantly different among the age groups.

Romans et al. (1965a) determined the composition of l. dorsi muscle tissue from 80 wholesale beef ribs. The ribs were divided equally among four maturity levels (A, B, C and D) and two marbling levels (slight and moderate). The results indicated that the differences in ether extract and moisture were non-significant among the maturity groups. However, the per cent protein of the A maturity group was significantly lower than that of the other three maturity levels.

These workers reported that fat and water content of l. dorsi tissue was closely related to marbling score. The higher level of marbling was accompanied by a higher fat content and lower moisture content.

Malkus and Henrickson (1964) studied Hereford heifers that were slaughtered at 3-month intervals between 9 and 18 months of age. After the first group was slaughtered, the remaining animals were fed a fattening ration until their assigned slaughter age was reached. The results of this study indicated that the per cent protein, moisture and ash in the boneless tissue of the left carcass side decreased with advancing animal age. The per cent ether extract was found to increase from 23.1 per cent in the 9-month heifers to 36.8 per cent in the 18-month group. Data obtained from a physical separation of the left side revealed that the percentage of muscle and bone decreased while the percentage of fat increased with advancing animal age.

Henrickson and Monroe (1965) used 36 Hereford heifers to investigate the effect of advancing animal age on the changes in carcass tissues. These workers noted that rib eye area closely paralleled total muscle weight during the period from 9 to 24 months of age. Average rib eye area increased from 5.9 sq. in. in the 9-month-old females to 12.3 sq. in. in the 24-month-old females, while the average fat-free muscle weight of the left sides of the carcasses increased from 70.6 to 143.5 pounds.

Jacobson and Fenton (1956a) found that beef muscles increased in size with increasing age in animals slaughtered at 32, 48, 64 and 80 weeks of age. Magee et al. (1958) reported a positive but low

correlation ($r=0.19$) between age and rib eye area in steers slaughtered at 410 to 505 days of age.

Wilson et al. (1954) studied the connective tissue content of l. dorsi muscle between the 12th and 13th rib of carcasses from animals differing in slaughter age. These workers found a significantly greater amount of collagen in veal samples than in the samples of either finished steers or mature cows with no significant difference between the two older groups. The average percentage of collagen on a dry, fat-free basis for the veal, steers and cows was 2.96, 1.89 and 1.84 per cent, respectively. This disagrees with the findings of Goll et al. (1963) who found no significant difference in the collagen content of fresh biceps femoris samples from veal, 15-month-old steers, 5-year-old cows and 10-year-old cows.

Bray et al. (1951) found that the moisture and ash content of connective tissue from cattle decreased with increasing animal age, but fat content was slightly higher in cow beef and Good grade beef as compared to veal.

Jacobson and Fenton (1956b) found that the iron content of bovine muscle tissue increased with increasing animal age. The differences in iron content due to age of the animal were highly significant for the l. dorsi and semimembranosus muscles, while significant differences were found for the psoas major muscle.

Romans et al. (1965b) found that the myoglobin and hemoglobin content of l. dorsi muscle increased with advancing maturity. However, the differences were only significant between the A level and the

B, C and D levels. The results of this study indicate that neither the slight nor moderate level of marbling had an influence on myoglobin or hemoglobin content.

Jacobson and Fenton (1956c) studied the effect of slaughter age on the vitamin B₁₂ content of the l. dorsi and semimembranosus muscles. These workers found that both muscles from animals slaughtered at 64 weeks of age contained significantly more vitamin B₁₂ than comparable muscles from animals slaughtered at 32 and 48 weeks of age.

II. MEAT CHARACTERISTICS

Nelson et al. (1930) studied the relationship between animal age and average total cooking losses of rib roasts. Average cooking losses decreased with increasing age in feeder cattle. The average cooking losses for roasts from feeder calves were 12.5 per cent and 10.6 per cent for two-year-old feeders. However, different results were obtained on comparable groups of cattle which had been fed a fattening ration for 150 days. The average total cooking losses for roasts from the fattened animals increased with animal age. The losses for roasts from fattened calves and two-year-olds were 12.7 and 15.4 per cent, respectively. The average total cooking losses for roasts from yearling cattle were intermediate in both comparisons. Increased fat content of the roast was accompanied by increased total cooking losses and higher dripping losses.

Lowe and Kastelic (1961) reported that the age of the animal did not affect the cooking losses of roasts from the l. dorsi and psoas major

muscles. Jacobsen and Fenton (1956a) found that the per cent weight and evaporation losses did not vary consistently with the age of the animal, yet the per cent drip and coagulum tended to decrease with increasing age.

Helser (1930) reported that muscle tissue from calves was a lighter red than muscle tissue from older cattle. Simone et al. (1959) found that meat from 30-month-old steers was darker than meat from 18-month-old steers. Tuma et al. (1963) observed that the red color of l. dorsi steaks became darker with advancing animal age. It was noted that these samples became lighter and brighter in color upon aging 14 days.

Jacobsen and Fenton (1956b) noted a highly significant increase in the hue (redness) of both raw and roasted samples from the semi-membranosus muscle with an increase of animal age from 32 to 80 weeks. However, objective color values of the l. dorsi and psoas major muscles were not significantly influenced by age of the animals.

Dunsing (1959) found that a consumer household panel preferred the color of the short loin from 30-month-old cattle over the short loin of 18-month-old cattle. On the other hand, the color of the sirloin cut from the younger carcasses was preferred.

Romans et al. (1965b) found that the value notation of color decreased significantly with increasing maturity, but the significant differences were only at the A maturity level.

Jacobsen and Fenton (1956b) found that no relationship existed between the age of the animals and the pH level in raw muscle tissue

when comparing 32-, 48-, 64- and 80-week-old animals. Research work by Tuma et al. (1963) indicated that the pH level of l. dorsi muscle was not significantly related to animal age, although a slight decrease with advancing animal age was noted.

Brady (1937) conducted histological studies on muscle tissue from yearling steers and mature cows. The diameter of muscle fibers from yearling steers was significantly smaller than fibers from mature cows. Palatability committee scores on texture indicated that yearling steer muscle had a slightly more desirable texture than mature cow muscle.

Hiner et al. (1953) reported a consistent increase in average muscle fiber diameter with increasing age of the animal. The diameter of muscle fibers from veal calves and 500-pound steer calves was not significantly different. However, highly significant differences were found between 500-pound steers and 900-pound steers, and between cows and 900-pound steers. Less active muscle fibers appeared to increase in size more than the more active fibers. A high correlation coefficient was obtained between fiber diameter and shear test results.

Histological studies by Tuma et al. (1962a) revealed that the diameter of fibers from the l. dorsi muscle gradually increased with increasing animal age. On the other hand, fiber diameter in the semi-tendinosus muscle increased between 6 and 18 months, and between 18 and 24 months, and then leveled off. Within age groups little relationship was found between fiber diameter and tenderness.

Romans et al. (1965a) noted a trend toward larger muscle fiber

diameters for the muscle fibers from more mature carcasses. Fiber diameters of C and D maturity levels were significantly larger than fibers from the B level, although none of these differed significantly from the A maturity level.

Henrickson and Monroe (1965) observed that muscle fiber diameter increased with animal age. The average muscle fiber diameter of the 9-month-old animals was 44.1 microns, whereas the average diameter of muscle fibers from the 24-month-old cattle was 66.9 microns. Although an increase in muscle fiber diameter was noted, the increase did not appear to account for the observed change in total muscle weight.

Dunsing (1959) utilized a consumer household panel to evaluate consumer preferences for visual characteristics of marbling. Results indicated that the marbling of both sirloin and short loin steaks from 30-month-old steers was consistently preferred over the marbling of comparable cuts from 18-month-old steers.

Harwin et al. (1961) reported a positive correlation ($r=0.32$) between marbling score and slaughter age in yearling steers.

Tuma et al. (1962b) found that the association between marbling and tenderness varied with animal age. The tenderness of 1. dorsi steaks from 18-month-old animals was not enhanced when "slightly abundant" was compared to a "slight" level of marbling. However, the "slightly abundant" level of marbling was associated with the more tender steaks from 42- and 90-month-old animals.

III. PALATABILITY

Palatability in beef is influenced by tenderness, flavor, juiciness and aroma, with tenderness generally being recognized as the most influential of these factors. Flavor, juiciness and aroma normally are evaluated by organoleptic tests. However, tenderness is evaluated by both sensory panels and mechanical devices.

Blumer (1963) recognized that the slaughter age of animals used in beef palatability studies must be considered an influencing variable and recommended that animal age should be acquired from birth records. If exact chronological age is unavailable, estimation of physiological age should be accomplished by evaluating meat and bone characteristics.

Helser (1930) reported that raw l. dorsi samples from calves required more pounds of force to shear than did comparable samples from yearling and two-year-old steers. These results suggest that meat from younger animals is less tender than meat from two-year-old animals. However, Mackintosh et al. (1936) found beef from mature steers to have higher shear values than beef from yearling steers. Brady (1937) observed that meat samples from mature cows required significantly more pounds of force to shear than did comparable samples from yearling steers.

Hiner and Hankins (1950) determined the resistance to shearing for nine different muscles from animals of different slaughter ages. Tenderness was shown to decrease in all muscles as age of the animal increased. The least amount of increase was noted for the psoas major muscle.

Jacobson and Fenton (1956a), King et al. (1958) and Goll et al. (1963) reported increasing shear values (decreasing tenderness) of beef with increasing animal age. On the other hand, Lowe and Kastelic (1961) reported that slaughter age of the animal did not affect shear force values.

Alsmeyer et al. (1959) showed a highly significant correlation ($r=0.24$) between slaughter age of animal and shear values for one-half-inch diameter cores from the l. dorsi muscle. Palmer (1963) reported a highly significant correlation ($r=0.27$) between slaughter age and shear values. Both of these studies showed decreasing tenderness in beef with advancing animal age.

Tuma et al. (1962b) found that shear force values increased with increasing age when comparing broiled l. dorsi steaks from Hereford females, 18, 42, and 90 months of age. Tuma et al. (1963) reported higher shear force values for broiled l. dorsi steaks from 6-month-old calves than comparable steaks from 18-month-old animals. Both of these groups required less shear force than 42- and 90-month-old animals, but the shear values for steaks from 42-month-old animals were only slightly lower than the values for 90-month-old animals.

Walter et al. (1963) used the L.E.E. Kramer test to study the effect of cooking on steaks from wholesale ribs representing A, B and F maturity levels. The results of the tests indicated that cooking significantly increased the tenderness of steaks from the younger maturity groups but had no influence on the tenderness of steaks from the more mature animals.

Goll et al. (1965) utilized the Warner-Bratzler and the L.E.E. Kramer shearing devices to measure the tenderness of rib steaks from animals of different chronological age and different marbling levels. The shear tests indicated that steaks from the younger animals were more tender than steaks from older animals. Marbling content did not appear to be related to tenderness as measured in the shear tests. Taste panel results substantiated the conclusions from the shear tests regarding the influence of age on tenderness and the association between marbling and tenderness.

Romans et al. (1965a) found no significant association between shear force values and carcass maturity. However, a trend for broiled l. dorsi steaks from more mature animals to have higher shear values than steaks from more youthful animals was observed.

Nelson et al. (1930) utilized an organoleptic panel to compare beef from calves, yearlings and two-year-old animals. The results indicated no significant differences in tenderness due to animal age. Brady (1937) used a palatability committee to compare tenderness of meat from yearling steers and mature cows. The committee indicated that meat from yearling steers was more tender than meat from mature cows.

Simone et al. (1959) reported that sensory panel tenderness scores favored meat from 18-month-old steers as compared to 30-month-old steers. Dunsing (1959) found that members of a consumer preference panel, who preferred steaks from 18-month-old steers to steaks from 30-month-old steers, indicated a pronounced preference for the tenderness of the steaks from the younger animals.

Alsmeyer et al. (1959) analyzed sensory panel tenderness scores for 1. dorsi steaks from 281 animals ranging from 5 to 87 months of age at slaughter. The results revealed a highly significant negative correlation ($r = -.28$) between sensory panel tenderness scores and slaughter age. Palmer (1963) reported a negative correlation ($r = -.25$) between slaughter age and sensory panel tenderness scores for 528 beef carcasses and concluded that slaughter age accounted for approximately 6 per cent of the variability of panel tenderness scores.

Tuma et al. (1962b) reported the results of sensory panel evaluation on 1. dorsi steaks from 18-, 42- and 90-month-old animals. Tenderness decreased significantly with increasing animal age. However, the decrease in tenderness was greater between 18- and 42-month-old animals than between 42- and 90-month-old animals. This difference between age groups was substantiated by shear force determinations with the Warner-Bratzler shear device. These results suggest that slaughter age may have a greater influence on tenderness at a point between 18 and 42 months than during the period between 42 and 90 months of age.

Tuma et al. (1963) obtained sensory panel evaluation data on broiled 1. dorsi steaks from 50 Hereford female and 6 Hereford steer carcasses. The animals were slaughtered at 6, 18, 42 and 90 months of age. Panel evaluation of broiled steak samples taken two days post-mortem indicated 18-month-old cattle were more tender than the 6-, 42- and 90-month-old cattle. However, panel evaluations conducted on steaks that had been aged 14 days indicated decreasing tenderness with increasing slaughter age. This would suggest that slaughter age may influence

the aging characteristics of beef. This study substantiates earlier work by Tuma et al. (1962b), indicating that a greater change in tenderness occurs between 18 and 42 months of age than between 42 and 90 months of age.

Romans et al. (1965a) compared sensory panel tenderness scores on broiled l. dorsi steaks from carcasses representing four levels of maturity (A, B, C and D). Generally, the steaks from the less mature carcasses were considered more tender than steaks from the more mature carcasses, but these differences were not significant.

Nelson et al. (1930) demonstrated that juiciness of beef roasts increased with increasing animal age, but flavor was not influenced by slaughter age. Barbella et al. (1939) studied the flavor and juiciness of 9-10-11 rib roasts from 728 heifer and steer cattle. These workers found that animal age had a highly significant influence on the flavor of muscle. A sensory panel indicated that lean meat from animals under 11 months of age possessed the least desirable flavor, although the desirability increased quite sharply with animals 11 to 18 months of age and generally continued to increase with animals 19 to 30 months of age. Intensity of flavor of lean generally increased with increasing animal age with the most noticeable change occurring between animals less than 11 months of age and those 11 to 18 months of age. Both flavor of fat and intensity of fat flavor were influenced by animal age and showed increasing desirability with increasing age. No precise trends were noted regarding the influence of animal age on either quality or quantity of juice. However, there was a slight

tendency for meat from cattle less than 11 months of age to possess more juice than other age groups.

Jacobson and Fenton (1956a) found that a palatability committee showed a preference for the aroma and flavor of roasts from dairy cattle 48 weeks of age as compared to animals 32, 64 and 80 weeks of age. These data suggested that beef from dairy animals might reach its optimum palatability when the animals were approximately one year old.

Simone et al. (1959) reported no significant difference in juiciness and flavor scores of rib roasts from 18- and 30-month-old steers. Dunsing (1959) observed that consumer panel members, who preferred steaks from 30-month-old cattle as compared to 18-month-old cattle, expressed strong preferences for the flavor and juiciness of the older animals.

Tuma et al. (1962b) observed that organoleptic panel scores for flavor and juiciness were not significantly associated with animal age. Tuma et al. (1963) noted that sensory panel juiciness scores indicated broiled 1. dorsi steaks from 42- and 90-month-old cattle were the most juicy followed by the 6- and 18-month-old cattle. However, animal age was not significantly associated with the sensory panel scores for flavor,

Romans et al. (1965a) found a significant difference between sensory panel flavor scores for 1. dorsi steaks representing B and D maturity levels. There was a trend for panel scores to favor the flavor of steaks from the more youthful cattle when A, B, C and D levels of maturity were compared. Maturity level was not significantly related to panel juiciness scores.

In a study by King et al. (1958) involving 57 cattle ranging in age from 5.9 to 166.0 months, animal age had a significant negative effect on the palatability of loin steaks and chuck roasts.

In recent years the U.S.D.A. grade specifications for beef quality, as amended in 1956, have been the object of constructive criticisms by meat researchers. Goll et al. (1965) hypothesized, from results of their research endeavors concerning the factors which influence beef tenderness, that some shift of emphasis in U.S.D.A. grade specifications for beef quality was justified. These researchers reported that shear force values and organoleptic evaluations showed little association of marbling with tenderness, juiciness or flavor. On the other hand, slaughter age of the animal seemed to be an important tenderness indicator. Romans et al. (1965a) asserted that results of their research suggested the effect of marbling on palatability may be over-emphasized. Further, the results implied that the magnitude of palatability differences may not be adequate to warrant the use of four separate maturity designations in the A, B, C and D range of carcass maturity. Briskey and Bray (1964) cited some of the literature in this review and postulated that some changes in the U.S.D.A. grade specifications were needed regarding carcass maturity. These workers proposed that the A and B levels of maturity be consolidated into A and that the C level be reclassified as B.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

Data were obtained from 138 females of varying chronological age in a four-year study in which the Angus and Hereford breeds were represented. The animals represented three of the beef cattle breeding herds of the University of Tennessee. The general criteria used in selecting the females under 24 months of age were poor daily gains prior to weaning, questionable inheritance, poor performance of dam and/or sire, undesirable conformation or a failure to exhibit a normal estrous cycle. The animals in the 24-month and older age groups represented females which were removed from the breeding herd due to a failure to conceive initially, failure to conceive after calving, low milk production, unacceptable performance by progeny or unfavorable pedigree. The actual chronological age of each animal at the time of slaughter was obtained from the birth records of each herd which are kept by the Animal Husbandry-Veterinary Science Department. The slaughter age of each animal was calculated to the nearest whole month. The daily gain figures for the heifers slaughtered at pre-weaning ages represent the average daily gain from birth to slaughter. Average daily gain from birth to weaning was used for animals slaughtered at post-weaning ages.

The animals were slaughtered during all seasons of the year. The pre-weaning age groups were sent to slaughter directly off their respective dams. The post-weaning age groups received only a normal maintenance ration prior to slaughter. The animals from the Ames Plantation herd were slaughtered at the Memphis Packing Plant in Memphis, Tennessee. The Plateau and Knoxville station cattle were slaughtered at the East Tennessee Packing Company in Knoxville, Tennessee.

II. CARCASS DATA

Data Obtained at Packing Plants

The animals were weighed individually at the respective packing plants prior to slaughter. Each carcass was tagged for identification immediately after sticking and prior to siding. Individual hot carcass weights were obtained after washing but prior to shrouding. After a 48-hour chill period, the following data were obtained from a Federal Grader: maturity, marbling score, conformation grade and U.S.D.A. quality grade. A tracing of a cross section of the l. dorsi muscle and surrounding tissues between the 12th and 13th ribs was made on acetate paper. The fat thickness over the l. dorsi muscle at the 12th rib was measured to the nearest millimeter at a point three-fourths the length of the l. dorsi from the 'chine end as described by Ramsey et al. (1962). The cross-sectional area of the l. dorsi muscle was measured to the nearest 0.01 square inch with a compensating polar planimeter. Carcass length represented the distance from the anterior edge of the first rib

to the anterior edge of the aitch bone of the right side of the carcass and was measured to the nearest 0.1 inch.

The wholesale rib (containing ribs 6 through 12) and the fore-shank from the left side of each carcass were removed in the usual manner and shipped to the Meat Laboratory for detailed cutting and analysis.

Data Obtained at the Meat Laboratory

Foreshank. After aging for seven days, samples of muscle tissue were removed from each foreshank, identified, wrapped and frozen. These samples were retained for histological studies.

Wholesale rib. The weight of the wholesale rib from the left side of each carcass was recorded to the nearest 0.1 pound. The 12th rib was removed by cutting close to the posterior edge of the 11th rib, trimmed, wrapped, identified and frozen. After approximately one-half hour, the 1. dorsi muscle color and fat color of each 6-11 rib section was subjectively evaluated by a meats researcher of the Animal Husbandry-Veterinary Science Department. Each rib section was given a numerical value for each trait. Values for muscle color were: 1 = "pale," 5 = "very dark red." There were values intermediate to these extremes. Fat color was scored with the use of the Munsell Color Paddles.

Each 6-11 rib section was divided into two sections by cutting close to the posterior edge of the 8th rib. A boneless roast was removed from the 6-7-8 rib section, wrapped, identified and frozen

for subsequent cooking tests, Warner-Bratzler shear tests and organoleptic evaluations.

Each 9-10-11 rib section was weighed and physically divided into separable muscle, fat and bone. These components were weighed individually to the nearest 0.1 pound. Each weight was expressed as a percentage of the original 9-10-11 rib section weight. After all external fat was removed from the excised l. dorsi muscle from the 9-10-11 rib section, the specific gravity of this muscle portion was determined, calculated and recorded as described by Backus (1958). After the specific gravity determination, the l. dorsi muscle from the 9-10-11 rib section was ground three times in a Hobart Model 4722 grinder equipped with a 3/32-inch plate and mixed thoroughly after each grinding. A representative sample of the ground muscle was placed in a two-ounce glass container, labeled and frozen for subsequent chemical analysis. 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 the combined tissue was ground to a paste consistency. A representative sample was frozen for future chemical analyses.

Chemical analyses of the 9-10-11 rib l. dorsi muscle and the boneless portion of the 9-10-11 rib section. Ground samples of l. dorsi muscle and 9-10-11 rib muscle and fat portions were removed from the freezer, thawed and samples were taken for analyses. Samples were analyzed for moisture, ether extract and protein in accordance with A.O.A.C. (1960) procedures with the exception of protein which was

determined by the Kjeldahl method with slight alterations. All chemical analyses of samples were conducted in triplicate. When the results of the closest two of a triplicate group differed by more than 2 per cent, the analysis was repeated.

Cooking losses of the 6-7-8 rib roast. All cooking for organoleptic tests and cooking loss studies was done by personnel of the Food Research Section of the College of Home Economics. The boneless 6-7-8 rib roasts were cooked in groups of four with each roast being randomly assigned within slaughter date to a particular cooking group. On the day prior to cooking, each roast was removed from the freezer, thawed for seven hours at room temperature and refrigerated overnight. The roasts were wiped free of foreign material, weighed to the nearest gram and placed fat side up on a rack in a roasting pan. A thermometer was inserted at the side of each roast so that the bulb was positioned in the center of the l. dorsi muscle. The roasts were cooked to an internal temperature of 68° C. in a Despatch Oven which was preheated to 163° C. Upon removal from the oven, the roasts were allowed to cool at room temperature for approximately 10 minutes, then the essential weights for cooking loss determinations were obtained. Evaporation loss was represented by the difference between the weight of the uncooked roast, pan and rack and the weight of the same components plus the drippings after cooking. Drip loss was calculated as the difference between the weight of the pan and rack prior to cooking and the weight of the rack, pan and drippings after cooking. Total cooking loss

represented the sum of the evaporation and drip losses. Two one-inch cores for shear tests and cross-sectional slices for sensory panel evaluation were taken from the l. dorsi muscle of each roast.

III. EVALUATION OF MEAT PALATABILITY

After each boneless 6-7-8 rib roast was cooked, as described previously, samples of the l. dorsi muscle were subjected to mechanical shear tests for tenderness and to organoleptic evaluation. Two cores one-inch in diameter were removed from each roast, allowed to cool at room temperature for one hour and sheared three times each with a Warner-Bratzler shearing device. The average of the six shear values was used in the statistical analysis. The experienced organoleptic panel consisted of six staff members of the Animal Husbandry-Veterinary Science, Food Technology and Home Economics Departments. Panel members individually scored a three-eighths inch cross-sectional slice from each roast for tenderness, juiciness and flavor. Each panel member received a sample from the same location within each l. dorsi muscle. Scoring was based on a nine-point hedonic scale, 9 representing "excellent" and 1 representing "extremely poor." The average of the six panel scores for each attribute was used for the statistical analysis.

IV. METHODS OF ANALYSIS

The data were statistically analyzed using the method of least squares as described by Harvey (1960). The actual chronological age

at slaughter of each animal was coded and consequently a constant was fitted for age effects. The effects of slaughter age were studied on a 6-month-interval basis (see Table I, page 26). When age effects were significant, the 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 on selected measures of carcass composition, meat characteristics and meat palatability.

CHAPTER IV

RESULTS AND DISCUSSION

I. GENERAL CHARACTERISTICS

Slaughter Age

The slaughter age of the females used in this study ranged from 3 to 211 months with an overall age mean of 50.1 months. Females from the Knoxville Station were oldest (51.3 months), while those from the Plateau were youngest (48.0 months). The average slaughter age of the Ames Plantation females (50.9 months) was intermediate to the above extremes. The slaughter age mean and number of animals within each age group are shown in Table I. Detailed data concerning slaughter age, slaughter weight, breed distribution and herd locations are presented in Table II.

Slaughter Weight

The slaughter weight of the animals ranged from 165 to 1,300 pounds and the overall mean was 848.1 pounds. Slaughter age had a significant ($P < .01$) influence on slaughter weight (Table III). Animals 84 to 89 months of age were significantly ($P < .01$) heavier at slaughter than all other age groups except 60 to 65-month-old animals. The 3 to 5-month-old heifer calves were significantly ($P < .01$) lighter at slaughter than the other age groups. Differences in the slaughter weights of 6 to 23-month-old animals were not significant. The least squares constants for the effects of slaughter age on slaughter weight are presented in Table IV. The least squares constants used throughout this

TABLE I
SLAUGHTER AGE MEAN AND NUMBER OF ANIMALS
WITHIN EACH AGE GROUP

Age group	Number of animals	Slaughter age mean
mo.		mo.
3-5	11	4.5
6-11	4	7.3
12-17	7	14.6
18-23	6	19.5
24-29	13	27.3
30-35	12	31.6
36-41	19	39.9
42-47	7	43.0
48-53	13	51.8
54-59	2	55.0
60-65	5	63.4
66-71	5	67.8
72-77	7	75.0
78-83	4	78.5
84-89	5	87.2
90-95	2	91.0
96-101	7	98.6
102 and over	9	136.7
Total	138	50.1

TABLE II

HERD LOCATION, BREED DISTRIBUTION, SLAUGHTER AGE AND SLAUGHTER WEIGHT

Herd location	Breed	Number of animals	Slaughter age		Slaughter weight	
			Mean	Range	Mean	Range
			mo.	mo.	lb.	lb.
Ames ^a	Angus	50	50.86	5-114	831.92	250-1144
Crossville ^b	Angus	45	47.98	3-211	805.67	165-1280
Knoxville ^c	Hereford	43	51.30	5-135	911.16	250-1300

^aAmes Plantation, Grand Junction, Tennessee.^bPlateau Experiment Station, Crossville, Tennessee.^cMain Experiment Station, Knoxville, Tennessee.

TABLE III

ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON SLAUGHTER
WEIGHT, MATURITY, CARCASS GRADE AND FAT THICKNESS

Source	d.f.	Mean square			
		Slaughter weight	Maturity	Carcass grades	Fat thickness
Age	17	430,943.43**	29.2344**	70.5920**	94.2785**
Residual	118	20,228.6	.6304	5.5785	25.5254

**P < .01.

TABLE IV

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON
SLAUGHTER WEIGHT, MATURITY, CARCASS GRADE
AND FAT THICKNESS

Age group mo.	Slaughter weight lb.	Maturity	Carcass grade	Fat thickness mm.
3-5	-636.2	-3.76 ^f	4.21 ^a	-7.40 ^d
6-11	-363.9 ^e	-3.38 ^{e,f}	5.39 ^a	-6.65 ^{c,d}
12-17	-320.4 ^e	-2.86 ^{e,f}	2.35 ^{a,b,c}	-4.53 ^{b,c,d}
18-23	-191.6 ^{d,e}	-2.49 ^{d,e}	3.72 ^{a,b,c}	-5.34 ^{c,d}
24-29	-82.7 ^{c,d}	-1.62 ^{c,d}	3.76 ^{a,b}	-.87 ^{a,b,c,d}
30-35	-22.7 ^{c,d}	-1.08 ^{b,c}	3.82 ^{a,b}	-.96 ^{a,b,c,d}
36-41	21.0 ^{b,c,d}	-.67 ^b	0.73 ^{c,d}	-.79 ^{a,b,c,d}
42-47	91.3 ^{a,b,c,d}	-.37 ^b	0.94 ^{b,c,d}	1.21 ^{a,b,c}
48-53	113.7 ^{a,b,c}	0.82 ^a	-2.21 ^{d,e}	0.35 ^{a,b,c}
54-59	101.4 ^{a,b,c,d}	0.60 ^{a,b}	-2.84 ^{d,e}	-.07 ^{a,b,c,d}
60-65	214.2 ^{a,b}	1.73 ^a	-3.02 ^e	1.68 ^{a,b,c}
66-71	151.6 ^{a,b,c}	1.22 ^a	-2.33 ^{d,e}	2.79 ^{a,b,c}
72-77	154.7 ^{a,b,c}	2.00 ^a	-2.94 ^e	3.33 ^{a,b,c}
78-83	78.3 ^{a,b,c,d}	2.04 ^a	-2.43 ^{d,e}	3.44 ^{a,b,c}
84-89	294.8 ^a	1.88 ^a	-2.07 ^{d,e}	4.35 ^{a,b}
90-95	188.1 ^{a,b,c}	2.12 ^a	-.86 ^{c,d,e}	3.35 ^{a,b,c}
96-101	38.5 ^{b,c,d}	1.72 ^a	-2.23 ^{d,e}	5.45 ^a
102 and over	149.9 ^{a,b,c}	2.10 ^a	-3.98 ^e	0.68 ^{a,b,c}
Arithmetic mean	848.05	4.62 ^g	12.07 ^h	8.64

a,b,c,d,e,f Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

^g₄ = C Maturity and 5 = D Maturity.

^h₁₂ = High Commercial and 13 = Low Standard.

discussion represent the effect of slaughter age on the respective variables discussed and are deviations from the overall mean for each variable.

Maturity

The maturity level of the carcasses ranged from veal to F with an overall maturity level mean of slightly less than D. Carcass maturity level was significantly ($P < .01$) influenced by slaughter age (Table III, page 28). The maturity level of carcasses from animals 48 months of age and older was significantly ($P < .01$) different from the maturity level of carcasses from younger animals, except there was no significant ($P < .01$) difference between the maturity of carcasses from animals 54 to 59 months of age and carcasses from animals 30 to 47-months-old. Carcasses from animals 3 to 17 months of age were scored significantly ($P < .01$) more youthful than carcasses from animals 24 to 35 months of age. Differences between the maturity level scores for carcasses from 6 to 23-month-old females were not significant ($P < .01$). A critical review of the least squares constants for the effects of slaughter age on carcass maturity level (Table IV, page 29) reveals that the Federal Graders generally were able to depict the maturity or physiological age differences which existed in carcasses from animals differing widely in chronological age at slaughter.

U.S.D.A. Quality Grade

The U.S.D.A. quality grades for the carcasses ranged from High Cutter to Average Prime and exhibited an overall mean of High Commercial. The average carcass grade for the Plateau Angus females (slightly under Low Standard) was approximately two-thirds of a grade higher than the

average carcass grade for the Knoxville Hereford females (slightly under Average Commercial) but only slightly higher than the Ames Plantation Angus females (slightly over High Commercial). Slaughter age was shown to exert a significant ($P < .01$) influence on the carcass quality grade (Table III, page 28). Females 11 months of age and younger were graded higher by the Federal Grader than females above 36 months of age. However, carcass grades for animals between 3 and 35 months of age were not significantly ($P < .01$) different. No significant difference was noted between the carcass grades of females 48 months of age and older. (The structure of the U.S.D.A. beef quality grade standards would offer a possible explanation for the lack of significant differences in the average grades of the age groups below 35 months of age and among the age groups above 48 months.) Generally, carcasses from animals under 35 months of age will not be graded lower than Low Standard, whereas, carcasses from animals over 48 months of age (commonly known as "hard-bone" cattle) generally are not graded above High Commercial. The least squares constants for the effects of slaughter age on carcass quality grade suggest a general decline in carcass quality grade with advancing chronological age from 3 through 65 months of age (Table IV, page 29).

Fat Thickness

Fat thickness over the 1. dorsi muscle between the 12th and 13th ribs ranged from 1 to 27 millimeters and the entire group of animals had a mean fat thickness of 8.6 millimeters. The Ames Plantation Angus females possessed approximately 2 millimeters more fat over the 1. dorsi muscle at the 12th rib than the Knoxville Hereford females which slightly

exceeded the overall mean. The Plateau Angus cattle were carrying the least fat over the l. dorsi muscle (6.1 millimeters). Since the post-weaning age groups were taken to slaughter directly off a maintenance ration, the fat thickness measurement might be considered a function of management and/or level of energy intake prior to slaughter.

The analysis of variance (Table III, page 28) indicated that chronological age of the females at slaughter had a significant ($P < .01$) influence on fat thickness over the l. dorsi muscle at the 12th rib. Females 96 to 101 months of age had significantly ($P < .01$) more fat over the l. dorsi muscle than the 3 to 23-month-old females, but were not significantly ($P < .01$) different from the other age groups. Differences in the fat thickness of 3 to 23- and 54 to 59-month-old animals were not significant. A general trend toward increased fat thickness with advancing slaughter age is displayed by the least squares constants for the effects of slaughter age on fat thickness (Table IV, page 29).

Wholesale Rib Weight

The arithmetical mean of the weights of the individual wholesale ribs (including ribs 6 through 12) was 21.4 pounds. The weight of the wholesale ribs ranged from 2.9 to 42.3 pounds. Reference to Table V will reveal that slaughter age had a significant ($P < .01$) influence on wholesale rib weight. Animals 84 to 89 months of age yielded a significantly ($P < .01$) heavier wholesale rib section than 41-month-old or younger animals, but wholesale rib weight differences were not significant ($P < .01$) for females 42 months of age and older. Malkus and Henrickson (1964) found an increased percentage of the beef carcass in

TABLE V

ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON WHOLESALE RIB
WEIGHT, 9-10-11 RIB SECTION WEIGHT AND WEIGHT OF
THE EXCISED L. DORSI MUSCLE FROM THE
9-10-11 RIB SECTION

Source	d.f.	Mean square		
		Wholesale rib weight	9-10-11 rib section weight	Excised <u>L. dorsi</u> muscle weight
Age	17	345.4857**	48.2604**	305,223.69**
Residual	118	18.1383	2.7673	14,671.30

**P < .01.

the wholesale rib with advancing age when comparing the carcasses of Hereford heifers slaughtered at 9, 12, 15 and 18 months of age. However, it should be noted that the heifers used by Malkus and Henrickson (1964) were full-fed a fattening ration from weaning (9 months of age) until slaughter, and that the fat thickness over the 1. dorsi muscle at the 12th rib increased from 0.2 inch in the 9-month-old group to 0.9 inch in the 18-month-old group. The results of the research reported herein generally substantiate the results of the cited study. The least squares constants for the effects of slaughter age on wholesale rib weight indicate that the most rapid change in rib weight occurred in the 3 to 35-month-old females (Table VI).

9-10-11 Rib Weight

Slaughter age had a significant ($P < .01$) influence on the average weights of the 9-10-11 rib sections (Table V, page 33). The weight of the 9-10-11 rib section from 84 to 89-month-old females was significantly ($P < .01$) heavier than the same cut from females 3 to 29 and 102 months of age or older. The 9-10-11 rib section from 3 to 5-month-old heifers was significantly ($P < .01$) lighter than all other groups except the 6 to 11-month-old heifers. A comparison of the least squares constants for the effects of slaughter age on both wholesale rib weight and 9-10-11 rib section weight indicated that the weights of the two cuts were closely associated (Table VI).

II. CARCASS COMPOSITION

Physical Composition of the 9-10-11 Rib Section

Hankins and Howe (1946) reported that physical composition of the 9-10-11 rib section was prominently related to total carcass composition.

TABLE VI

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON WHOLESALE RIB WEIGHT, 9-10-11 RIB SECTION WEIGHT AND WEIGHT OF THE EXCISED L. DORSI MUSCLE FROM THE 9-10-11 RIB SECTION

Age group	Wholesale rib weight	9-10-11 rib section weight	Excised l. dorsi muscle weight
mo.	lb.	lb.	lb.
3-5	-17.22	-6.38 ^f	-499.52
6-11	-13.18 ^e	-4.66 ^{e,f}	-405.61 ^g
12-17	-8.37 ^{d,e}	-3.01 ^{d,e}	-210.23 ^{f,g}
18-23	-4.44 ^{c,d}	-1.84 ^{c,d,e}	-125.41 ^{e,f}
24-29	-1.99 ^{b,c,d}	-.94 ^{c,d}	-84.94 ^{d,e,f}
30-35	0.18 ^{b,c,d}	-.03 ^{b,c}	26.36 ^{c,d,e}
36-41	-.29 ^{b,c,d}	0.00 ^{b,c}	-4.72 ^{c,d,e}
42-47	1.03 ^{a,b,c}	0.56 ^{a,b,c}	36.68 ^{b,c,d,e}
48-53	2.84 ^{a,b}	0.86 ^{a,b,c}	92.57 ^{a,b,c}
54-59	0.77 ^{a,b,c,d}	-.20 ^{b,c,d}	-50.68 ^{c,d,e,f}
60-65	6.93 ^{a,b}	2.69 ^{a,b}	239.26 ^{a,b}
66-71	3.41 ^{a,b}	1.43 ^{a,b}	113.36 ^{a,b,c}
72-77	4.19 ^{a,b}	1.81 ^{a,b}	150.14 ^{a,b,c}
78-83	1.12 ^{a,b,c}	0.63 ^{a,b,c}	64.67 ^{a,b,c,d}
84-89	7.39 ^a	3.40 ^a	262.72 ^a
90-95	7.31 ^{a,b}	1.99 ^{a,b,c}	126.77 ^{a,b,c}
96-101	5.88 ^{a,b}	2.28 ^{a,b}	183.18 ^{a,b,c}
102 and over	4.42 ^{a,b}	-1.35 ^{c,d}	85.40 ^{a,b,c}
Arithmetic mean	21.42	8.07	728.60

a,b,c,d,e,f,g. Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

Cole et al. (1960) found a significant ($P < .01$) positive association ($r = 0.74$) between the separable muscle in the left side of the beef carcass and the separable muscle in the 9-10-11 rib section of the same carcass side. Thus, the physical analysis of the 9-10-11 rib sections was conducted in conjunction with the research reported herein to examine possible differences in the physical composition of carcasses from beef females differing in slaughter age. Slaughter age had a significant ($P < .01$) effect on the yield of separable muscle from the 9-10-11 rib section (Table VII). Three to five-month-old heifers yielded a higher percentage of the 9-10-11 rib section in separable muscle than did any other age group. The yield of separable muscle from the 9-10-11 rib section was not significantly ($P < .01$) different for 3 to 5- and 6- to 11-month-old heifers, nor were the differences in separable muscle yield significant ($P < .01$) among the females 6 months of age or older.

The percentage yield of separable fat from the 9-10-11 rib section was significantly ($P < .01$) influenced by slaughter age (Table VII). The separable fat yield of the 9-10-11 rib section from 3 to 5-month-old heifers was significantly ($P < .01$) less than all the females over 23 months of age except those in the 54 to 59-month-old group. However, the yield of separable fat from the 9-10-11 rib section did not significantly ($P < .01$) differ among females 3 to 23 and 54 to 59 months of age. The least squares constants for the effect of slaughter age on percentage yield of separable muscle and fat from the 9-10-11 rib section portray the existence of an inverse relationship between the content of these physical components in the beef carcass

TABLE VII

ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON THE
PHYSICAL COMPOSITION OF THE 9-10-11 RIB SECTION

Source	d.f.	Mean square		
		Per cent separable muscle	Per cent separable fat	Per cent separable bone
Age	17	178.7476**	234.2105**	16.7818
Residual	118	52.3923	63.6750	10.0162

**P < .01.

(Table VIII). The results of this research are in accord with the work reported by Malkus and Henrickson (1964). These workers found that separable muscle and fat were inversely related when the left carcass sides of 24 Hereford heifers, slaughtered at 9, 12, 15 and 18 months of age, were physically analyzed. The percentage of the 9-10-11 rib section accounted for by bone was not significantly ($P < .05$) different among the age groups (Table VII, page 37). The influence of age on the percentage of muscle, fat and bone of the 9-10-11 rib section of the left carcass side is graphically presented in Figure 1.

Chemical Analyses of the Combined Muscle and Fat Tissues of the 9-10-11 Rib Section

Slaughter age significantly ($P < .01$) influenced the moisture, ether extract and crude protein content of the blended muscle and fat tissues of the 9-10-11 rib section (Table IX). The influence of age on the percentage of moisture, ether extract and crude protein of the boneless portion of the 9-10-11 rib section is graphically presented in Figure 2. The combined muscle and fat tissues of the 9-10-11 rib section from 3 to 5-month-old females contained significantly ($P < .01$) more moisture than did the same tissues from females 12 months of age and older, yet differences existing between the 3 to 5- and 6 to 11-month-old females were not significant ($P < .01$). Muscle and fat tissues of the 9-10-11 rib section from females 6 to 11 months of age possessed significantly ($P < .01$) more moisture than did the 84 to 89- and 96 to 101-month-old groups.

TABLE VIII

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON 9-10-11
RIB SECTION WEIGHT AND PHYSICAL COMPONENTS
OF THE 9-10-11 RIB SECTION

Age group	9-10-11 rib section weight	Separable muscle	Separable fat	Separable bone ^a
mo.	lb.	%	%	%
3-5	-6.38 ^g	14.56 ^b	-15.25 ^c	1.61
6-11	-4.66 ^{f,g}	6.00 ^{b,c}	-6.14 ^{b,c}	1.46
12-17	-3.01 ^{e,f}	2.56 ^c	-4.08 ^{b,c}	1.00
18-23	-1.84 ^{d,e,f}	2.92 ^c	-3.20 ^{b,c}	0.62
24-29	-.94 ^{d,e}	-.82 ^c	0.40 ^b	0.85
30-35	0.03 ^{c,d}	1.09 ^c	-.17 ^b	-.35
36-41	0.00 ^{c,d}	1.22 ^c	-1.08 ^b	0.74
42-47	0.56 ^{b,c,d}	-.46 ^c	1.61 ^b	-1.12
48-53	0.86 ^{b,c,d}	-1.09 ^c	-.06 ^b	1.75
54-59	-.20 ^{c,d,e}	2.15 ^c	-2.58 ^{b,c}	1.64
60-65	2.69 ^{b,c}	-.79 ^c	3.08 ^b	-.97
66-71	1.43 ^{b,c}	-2.74 ^c	2.87 ^b	0.29
72-77	1.81 ^{b,c}	-1.81 ^c	-2.12 ^b	0.14
78-83	0.63 ^{b,c,d}	-.72 ^c	1.51 ^b	-.43
84-89	3.40 ^b	-5.03 ^c	9.54 ^b	-3.55
90-95	1.99 ^{b,c,d}	-5.08 ^c	7.85 ^b	-1.95
96-101	2.28 ^{b,c}	-4.57 ^c	8.13 ^b	-3.33
102 and over	-1.35 ^{d,e}	-.49 ^c	-.31 ^b	1.59
Arithmetic mean	8.07	52.37	29.42	17.87

^aSlaughter age did not significantly affect this factor at the 0.05 level of probability.

^{b,c,d,e,f,g}Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

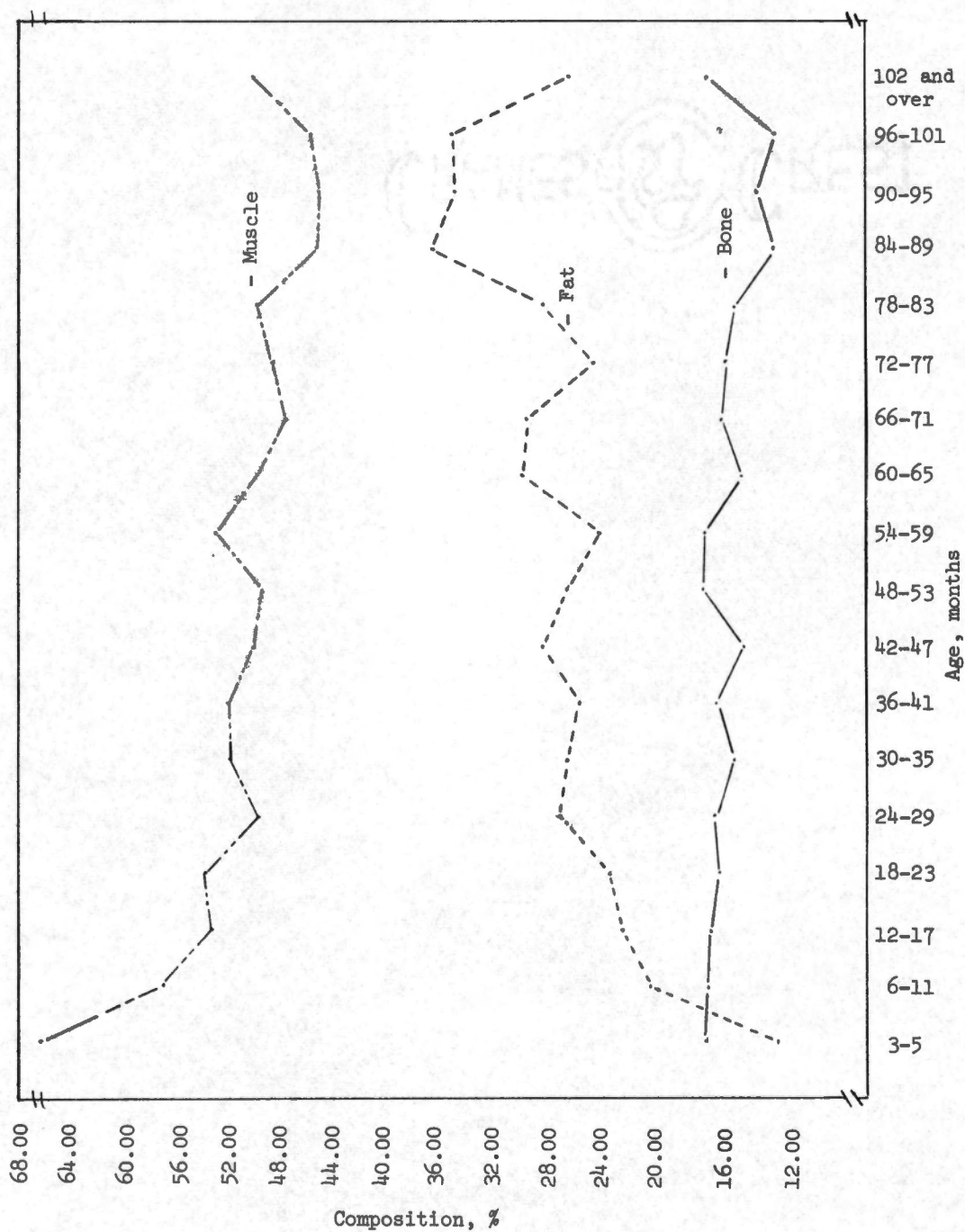


Figure 1. Influence of age on the percentage of separable muscle, fat and bone of the 9-10-11 rib section of the left carcass side.

TABLE IX
ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON
THE CHEMICAL COMPONENTS OF THE BONELESS
PORTION OF THE 9-10-11 RIB SECTION

Source	d.f.	Mean square		
		Per cent crude protein	Per cent ether extract	Per cent moisture
Age	17	17.0293**	444.4723**	265.7595**
Residual	118	6.3483	86.9881	49.8424

**P < .01.

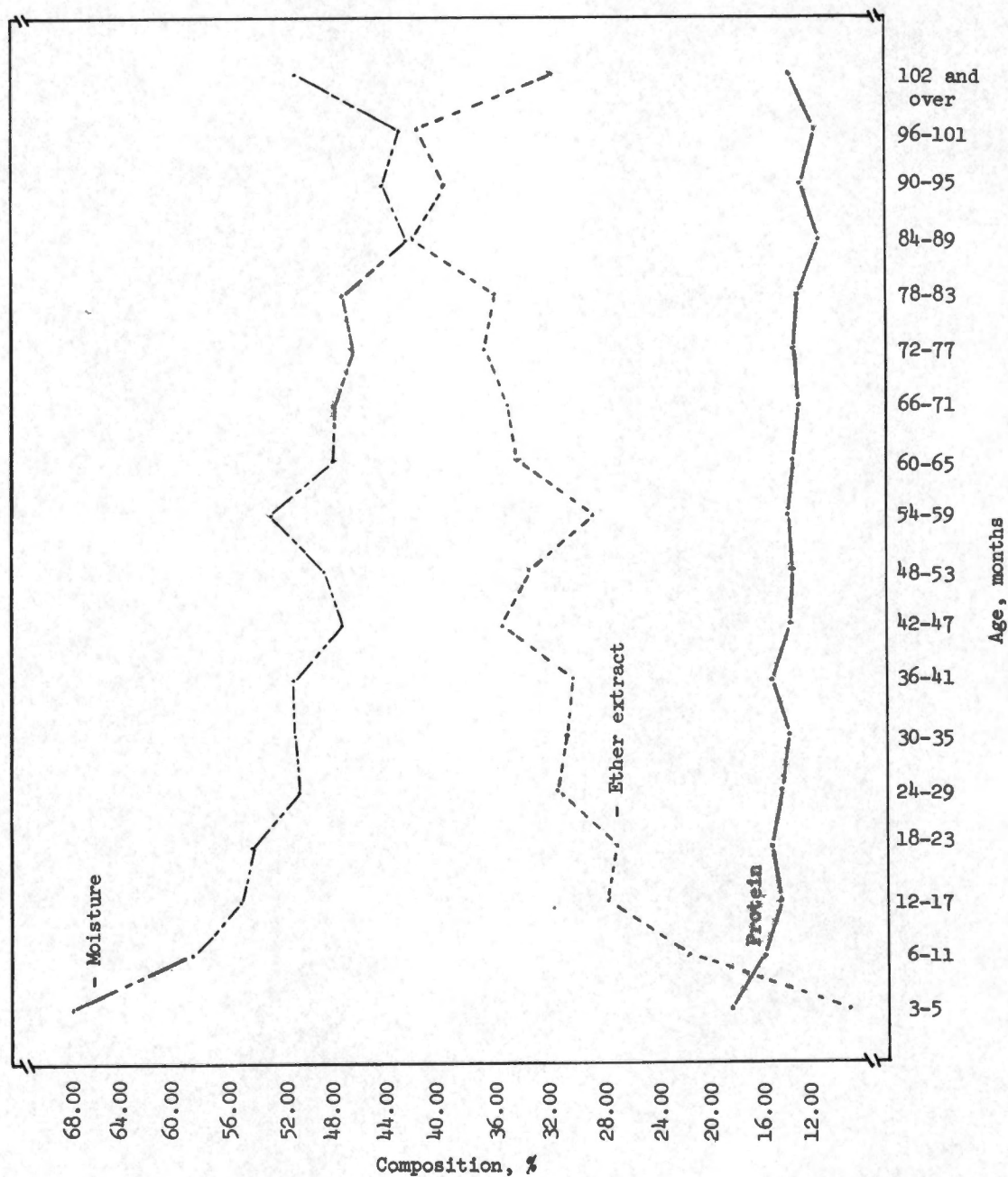


Figure 2. Influence of age on the percentage of moisture, ether extract and crude protein of the boneless portion of the 9-10-11 rib section of the left carcass side.

However, differences in the moisture content of the 9-10-11 rib section muscle and fat tissues from beef females 12 months of age or older were not significant ($P < .01$).

The ether extract content of the combined muscle and fat tissues of the 9-10-11 rib section from 3 to 5-month-old females was significantly ($P < .01$) less than the ether extract content of comparable samples from females 12 months of age or older. Differences in the ether extract content of the boneless portion of the 9-10-11 rib section from 3 to 5- and 6 to 11-month-old females were not significant ($P < .01$). However, the ether extract content of samples from 6 to 11-month-old females was significantly ($P < .01$) less than the ether extract content of comparable samples from females 84 to 89 and 96 to 101 months of age. Variations in the ether extract content of 9-10-11 rib boneless tissue samples representing females 12 months of age or older were not significant ($P < .01$).

The crude protein content of the boneless tissue of the 9-10-11 rib section from 3 to 5-month-old females was significantly ($P < .01$) greater than the crude protein content of comparable samples from beef females 42 months of age and older except for the 54 to 59-month-old group. Differences in the crude protein content of the boneless portion of the 9-10-11 rib section from females 3 to 41 and 54 to 59 months of age were not significant ($P < .01$). Further, the crude protein content was not significantly ($P < .01$) different among beef females 6 months of age and older. The least squares constants for the effect of slaughter age on moisture, ether extract and crude protein of the

boneless portion of the 9-10-11 rib section are presented in Table X. The constants indicate that crude protein and moisture content of the boneless portion of the 9-10-11 rib section generally decreased with advancing animal age, while the ether extract content generally increased with advancing animal age. These results are in agreement with the work of Malkus and Henrickson (1964) who reported that advancing animal age was accompanied by decreased crude protein and moisture content of the blended muscle and fat tissues of the 9-10-11 rib section. Further, their work indicates that ether extract increased with advancing animal age.

Weight of the Excised L. Dorsi Muscle From the 9-10-11 Rib Section

Chronological age of females at slaughter had a significant ($P < .01$) influence on the weight of the excised l. dorsi muscle from the 9-10-11 rib section (Table V, page 34). Females 84 to 89 months of age yielded significantly ($P < .01$) heavier l. dorsi muscle portions from the 9-10-11 rib section than did females 59 months of age and younger except the 48 to 53-month-old group, which was not significantly ($P < .01$) different from the 84 to 89-month-old group. Heifers 3 to 5 months of age yielded significantly ($P < .01$) lighter 9-10-11 rib section l. dorsi muscle weights than the other age groups. The least squares constants for the effects of slaughter age on the weight of the excised 9-10-11 rib l. dorsi muscle indicated that the muscle increased most rapidly in weight between 3 and 29 months of age (Table VI, page 35). This would suggest that the l. dorsi is an early maturing

TABLE X

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON 9-10-11
RIB SECTION WEIGHT AND THE CHEMICAL COMPOSITION OF THE
BONELESS PORTION OF THE 9-10-11 RIB SECTION

Age group	9-10-11 rib section weight	Crude protein	Ether extract	Moisture
mo.	lb.	%	%	%
3-5	-6.38 ^f	4.13 ^a	-21.90 ^c	16.82 ^a
6-11	-4.66 ^{e,f}	1.62 ^{a,b}	-10.34 ^{b,c}	8.06 ^{a,b}
12-17	-3.01 ^{d,e}	0.53 ^{a,b}	-4.17 ^{a,b}	4.51 ^{b,c}
18-23	-1.84 ^{c,d,e}	1.16 ^{a,b}	-4.80 ^{a,b}	3.67 ^{b,c}
24-29	-.94 ^{c,d}	0.34 ^{a,b}	-.44 ^{a,b}	0.07 ^{b,c}
30-35	-.03 ^{b,c}	-.11 ^{a,b}	-1.15 ^{a,b}	0.57 ^{b,c}
36-41	0.00 ^{b,c}	1.15 ^{a,b}	-1.59 ^{a,b}	0.74 ^{b,c}
42-47	0.56 ^{a,b,c}	-.24 ^b	3.55 ^{a,b}	-3.00 ^{b,c}
48-53	0.86 ^{a,b,c}	-.38 ^b	1.58 ^{a,b}	-1.69 ^{b,c}
54-59	-.20 ^{b,c,d}	-.05 ^{a,b}	-2.95 ^{a,b}	2.31 ^{b,c}
60-65	2.69 ^{a,b}	-.39 ^b	2.40 ^{a,b}	-2.33 ^{b,c}
66-71	1.43 ^{a,b}	-.87 ^b	3.28 ^{a,b}	-2.44 ^{b,c}
72-77	1.81 ^{a,b}	-.44 ^b	4.94 ^{a,b}	-3.82 ^{b,c}
78-83	0.63 ^{a,b,c}	-.69 ^b	4.04 ^{a,b}	-2.98 ^{b,c}
84-89	3.40 ^a	-2.33 ^b	10.40 ^a	-7.74 ^c
90-95	1.99 ^{a,b,c}	-1.04 ^b	7.64 ^{a,b}	-5.97 ^{b,c}
96-101	2.28 ^{a,b}	-2.08 ^b	9.77 ^a	-7.13 ^c
102 and over	-1.35 ^{c,d}	-.31 ^b	-.27 ^{a,b}	0.33 ^{b,c}
Arithmetic mean	8.07	15.19	32.54	50.80

a,b,c,d,e,f Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

muscle and that the increased weight in the excised l. dorsi muscle of older females (such as the 84 to 89-month-old group) could be attributed to increased intramuscular fat content.

Chemical Analyses of the Excised L. Dorsi Muscle From the 9-10-11 Rib Section

The analysis of variance (Table XI) indicated that slaughter age did not significantly ($P < .05$) influence the crude protein content of the l. dorsi muscle. This is in agreement with the work of Tuma et al. (1962b) who reported no significant difference in the protein content of l. dorsi muscle from 18-, 42- and 90-month-old cattle. The least squares constants (Table XII) for the effects of age on crude protein content of the l. dorsi muscle follow an irregular pattern. Although age did not significantly ($P < .05$) influence the crude protein content of the l. dorsi muscle, a comparison of the arithmetic means for the crude protein content of the boneless portion of the 9-10-11 rib section (15.2) and the l. dorsi muscle (21.1) vividly depicts the superiority of muscle tissue as a source of protein.

Slaughter age exerted a significant ($P < .01$) influence on the ether extract content of the l. dorsi muscle (Table XI). Females 84 to 89 months of age had significantly ($P < .01$) more ether extract in the l. dorsi muscle than did females 35 months of age or younger. However, no significant ($P < .01$) difference in the ether extract content of the l. dorsi muscle was found among the females over 35 months of age. The l. dorsi muscle of 3 to 5-month-old heifers contained significantly

TABLE XI

ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON
 CHEMICAL COMPONENTS OF THE EXCISED L. DORSI
 MUSCLE FROM THE 9-10-11 RIB SECTION

Source	d.f.	Mean square		
		Per cent crude protein	Per cent ether extract	Per cent moisture
Age	17	1.1731	20.5603**	18.2709**
Residual	118	1.0794	5.1111	3.5617

**P < .01.

TABLE XII

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON THE
CHEMICAL COMPONENTS OF THE EXCISED L. DORSI MUSCLE
FROM THE 9-10-11 RIB SECTION

Age group	<u>L. dorsi</u> crude protein ^a	<u>L. dorsi</u> ether extract	<u>L. dorsi</u> moisture
mo.	%	%	%
3-5	-.24	-3.66 ^e	3.38 ^b
6-11	-1.23	-2.79 ^{d,e}	3.10 ^{b,c}
12-17	0.66	-1.60 ^{d,e}	1.64 ^{b,c,d}
18-23	-.40	-1.80 ^{d,e}	1.43 ^{b,c,d}
24-29	-.11	-.66 ^{c,d,e}	0.31 ^{c,d,e}
30-35	-.03	-.40 ^{c,d,e}	0.26 ^{c,d,e}
36-41	0.03	0.31 ^{b,c,d,e}	0.13 ^{c,d,e}
42-47	0.01	0.61 ^{b,c,d,e}	-.65 ^{d,e}
48-53	-.41	0.45 ^{b,c,d,e}	-.16 ^{c,d,e}
54-59	-.07	-.31 ^{b,c,d,e}	0.52 ^{b,c,d,e}
60-65	-.16	0.15 ^{b,c,d,e}	0.41 ^{c,d,e}
66-71	0.61	0.81 ^{b,c,d,e}	-1.10 ^{d,e}
72-77	0.28	0.66 ^{b,c,d,e}	-1.03 ^{d,e}
78-83	0.61	0.05 ^{b,c,d,e}	-.70 ^{d,e}
84-89	0.02	3.50 ^b	-3.11 ^e
90-95	0.62	2.20 ^{b,c,d}	-2.26 ^{d,e}
96-101	0.28	2.57 ^{b,c}	-2.44 ^e
102 and over	-.47	-.08 ^{b,c,d,e}	0.26 ^{c,d,e}
Arithmetic mean	21.07	4.11	73.10

^aSlaughter age did not significantly affect this factor at the 0.05 level of probability.

^{b,c,d,e} Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

($P < .01$) less ether extract than did the 84 to 101-month-old females, yet there was no significant ($P < .01$) difference between 3 to 5-month-old heifers and females 102 months of age and older. These findings are not in accord with the work of Tuma et al. (1962b) who found no significant differences in ether extract content of l. dorsi muscle tissue taken from 18-, 42- and 90-month-old Hereford females.

The moisture content of the l. dorsi muscle was significantly ($P < .01$) influenced by slaughter age (Table XI, page 47). The moisture content of l. dorsi muscle samples from 3 to 5-month-old heifers was significantly ($P < .01$) greater than comparable samples from females 24 months of age or older except for the 54 to 59-month-old group. No significant ($P < .01$) differences were found in the moisture content of l. dorsi muscle from beef females 24 months of age or older. Although slaughter age significantly influenced the moisture content of the l. dorsi muscle, these results substantiate the work of Tuma et al. (1962b) who found no significant difference in the moisture content of l. dorsi muscle from 18-, 42- and 90-month-old bovine females.

A thorough comparison of the least squares constants for the slaughter age effects on moisture and ether extract content of the l. dorsi muscle (Table XII, page 48) reveals the existence of an inverse relationship between these muscle components. The constants indicate a general increase in the ether extract content of the l. dorsi muscle with advancing slaughter age through 101 months. A graphical presentation of the influence of age on the per cent ether extract, moisture and crude protein of the excised l. dorsi

muscle from the 9-10-11 rib section is shown in Figure 3.

III. MEAT CHARACTERISTICS

Cooking Losses of the Boneless 6-7-8 Rib Roast

Slaughter age significantly ($P < .01$) influenced the percentage drip loss from boneless 6-7-8 rib roasts (Table XIII). Roasts from females 42 months of age or older showed significantly ($P < .01$) greater drip losses than did comparable roasts from younger animals except for 54 to 59- and 78 to 83-month-old groups which were not significantly ($P < .01$) different from the age groups under 41 months of age. The overall mean for drip loss from the boneless 6-7-8 rib roasts was 5.2 per cent. The least squares constants for the effects of slaughter age on drip losses (Table XIV) reveal that the percentage drip loss from boneless 6-7-8 rib roasts of all the females under 42 months of age was below average. Although the drip losses of the roasts from females 54 to 59, 78 to 83 and over 101 months of age were below average, there was a slight trend toward greater drip losses with advancing animal age. The increases in drip losses generally paralleled the increases in 9-10-11 rib section per cent separable fat which suggest that fatter roasts can be expected to show a greater drip loss during cooking. These findings support the work of Jacobson and Fenton (1956a) who found that the drip losses from roasts representing cattle 32, 48, 64 and 80 weeks of age tended to increase with increasing animal age.

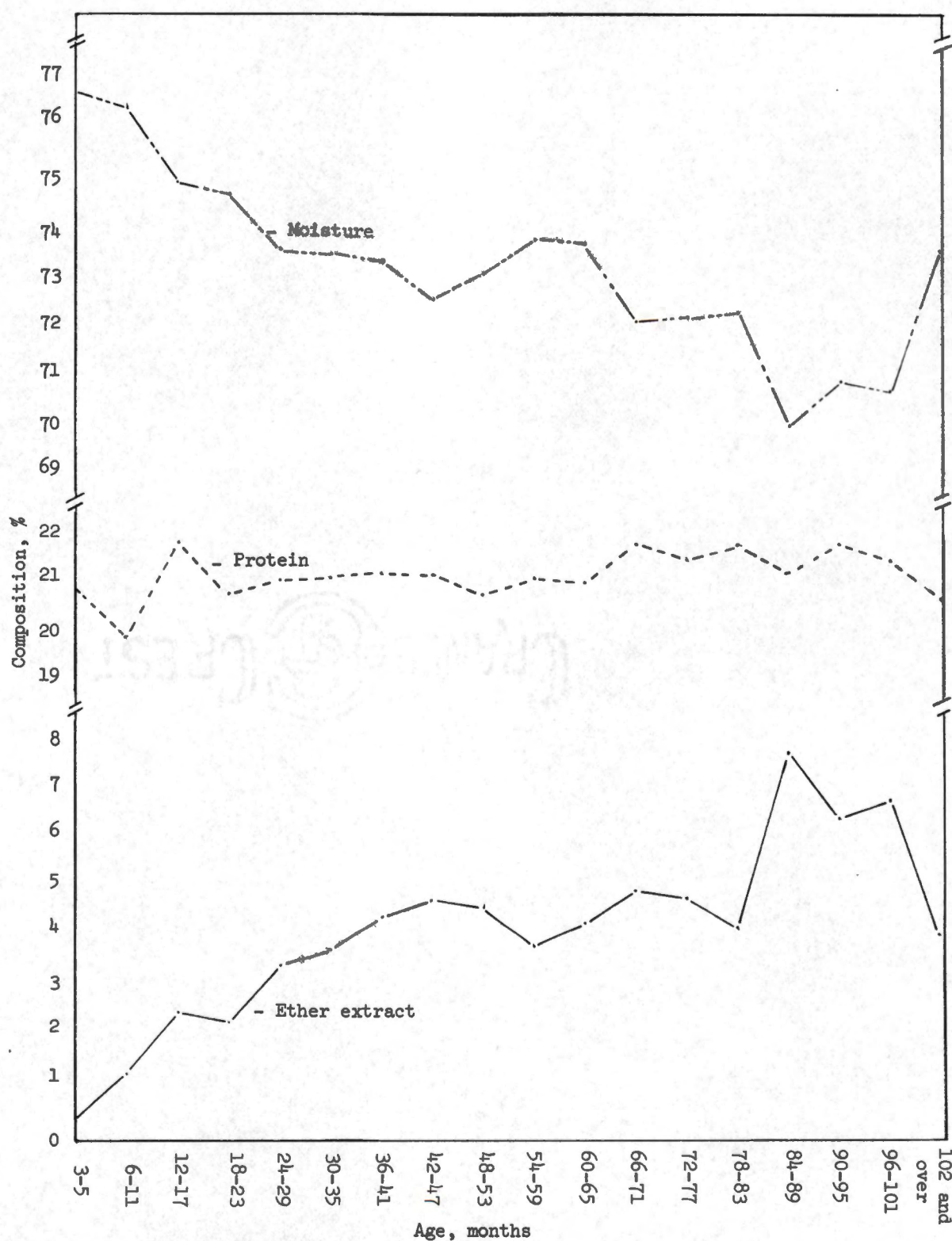


Figure 3. Influence of age on the per cent ether extract, moisture and crude protein of the excised 1. dorsii muscle from the 9-10-11 rib section of the left carcass side.

TABLE XIII
ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON
COOKING LOSSES OF BONELESS 6-7-8 RIB ROASTS

Source	d.f.	Mean square		
		Per cent drip loss	Per cent evaporation loss	Per cent total losses
Age	17	11.9875**	7.2121	24.7661**
Residual	118	2.8222	5.1005	5.5318

**P < .01.

TABLE XIV
LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON
COOKING LOSSES OF BONELESS 6-7-8 RIB ROASTS

Age group	Drip loss	Evaporation loss ^a	Total losses
mo.	%	%	%
3-5	-2.38 ^c	0.47	-1.92 ^{b,c}
6-11	-1.90 ^{b,c}	-1.34	-3.25 ^c
12-17	-1.99 ^{b,c}	-1.18	-3.18 ^{b,c}
18-23	-.72 ^{b,c}	-1.20	-1.94 ^{b,c}
24-29	-.72 ^{b,c}	-1.70	-2.43 ^{b,c}
30-35	-.68 ^{b,c}	-.21	-.91 ^{b,c}
36-41	-.89 ^{b,c}	-.29	-1.20 ^{b,c}
42-47	0.59 ^b	-.37	0.48 ^{b,c}
48-53	0.03 ^b	1.12	1.13 ^b
54-59	-.86 ^{b,c}	1.70	0.84 ^{b,c}
60-65	1.81 ^b	0.77	2.58 ^b
66-71	0.95 ^b	-.57	0.36 ^{b,c}
72-77	1.20 ^b	0.65	1.83 ^b
78-83	-.04 ^{b,c}	0.57	0.51 ^{b,c}
84-89	1.75 ^b	-.91	0.83 ^{b,c}
90-95	2.13 ^b	0.47	2.59 ^b
96-101	1.76 ^b	0.59	2.32 ^b
102 and over	-.04 ^b	1.42	1.37 ^b
Arithmetic mean	5.18	15.63	20.82

^aSlaughter age did not significantly affect this factor at the 0.05 level of probability.

^{b,c}Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly ($P < .01$).

Evaporation losses were not significantly ($P < .05$) influenced by slaughter age (Table XIII, page 52). The overall mean for evaporation losses from the boneless 6-7-8 rib roast was 15.6 per cent. The least squares constants for the effects of age on evaporation losses (Table XIV, page 53) were negative for all age groups under 48 months of age except the 3 to 5-month-old heifers. All the age groups over 47 months of age had positive constants except the 66 to 71- and 84 to 89-month-old group. Generally, the constants fail to portray a definite trend in percentage evaporation loss as influenced by slaughter age. These results agree with the work of Jacobson and Fenton (1956a) who reported that evaporation losses did not vary consistently with the age of the animal when roasts from 32-, 48-, 64- and 80-week-old animals were compared.

Total cooking losses from the boneless 6-7-8 rib roasts were significantly ($P < .01$) affected by slaughter age (Table XIII, page 52). The arithmetic mean for total losses from the roasts during the cooking period was 20.8 per cent. Roasts from 6 to 11-month-old females had the least total loss during cooking and had significantly ($P < .01$) less total loss than did roasts from females 48 to 53, 60 to 65, 72 to 77 and over 89 months of age. The least squares constants for the effects of age on total cooking losses (Table XIV, page 53) suggest a general trend toward increased total cooking losses with increasing slaughter age. These results contradict the work of Nelson et al. (1930) who found that the average total cooking losses for roasts from feeder calves were greater than the losses for roasts from two-year-old

cattle. Figure 4 shows the influence of age on the percentage drip loss, evaporation loss and total cooking losses of boneless 6-7-8 rib roasts.

Marbling Score

Marbling scores were significantly ($P < .01$) influenced by the chronological age of beef females at slaughter (Table XV). Females 84 to 89 months of age had significantly ($P < .01$) higher marbling scores than did females 23 months of age or younger. Three to five-month-old heifers had significantly ($P < .01$) lower marbling scores than did females over 23 months of age, but differences in the marbling scores of females from 3 to 23 months of age were not significant ($P < .01$). The overall mean marbling score for the 138 females was 4.7 (slightly under the "small" degree of marbling.) The mean marbling scores for the Ames Plantation and Plateau Station Angus females exceeded the overall mean, whereas the mean marbling score for the Knoxville Hereford females was below the overall mean. The mean marbling score for each herd location was as follows: Ames Plantation, 5.1; Knoxville, 3.6; Plateau Station, 5.2. The marbling scores for the female age groups over 29 months of age exceeded the overall mean in all cases except the 60 to 65-month-old and the 102-month-old and older groups. A critical review of the least squares constants for the effects of slaughter age on marbling score revealed a slight trend toward higher marbling scores with advancing slaughter age through 101 months of age (Table XVI).

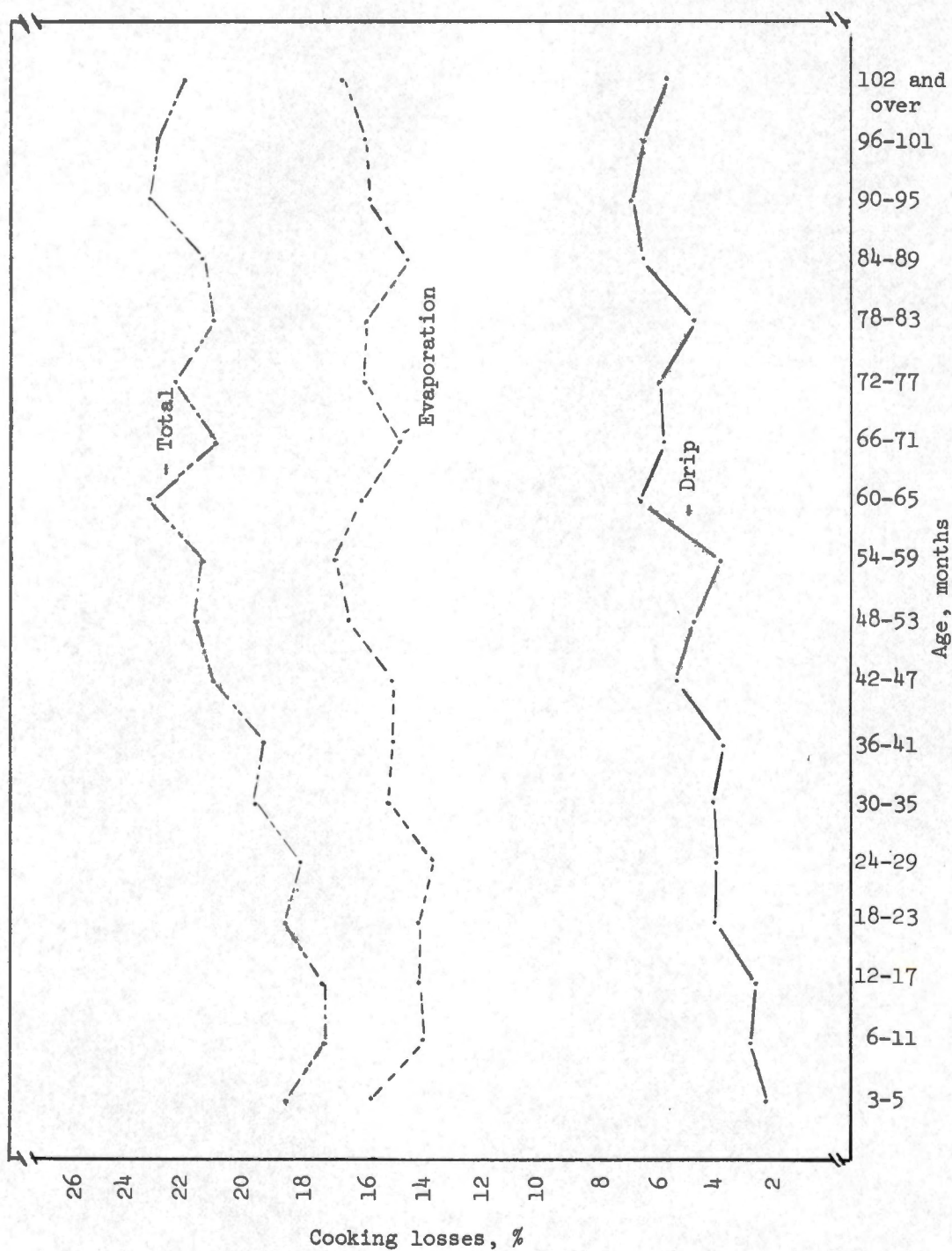


Figure 4. Influence of age on the percentage drip, evaporation and total cooking losses of boneless 6-7-8 rib roast.

TABLE XV
ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE
ON SELECTED MEAT CHARACTERISTICS

Source	d.f.	Mean square			
		Marbling score	Fat color	Muscle color	Specific gravity ^a
Age	17	9.7742**	14.3506**	3.5915**	6,570.1786*
Residual	118	2.2562	1.2057	0.3437	3,825.3700

^aSpecific gravity of the excised 1. dorsi muscle from the 9-10-11 section.

*P < .05.

**P < .01.

Muscle Color

Slaughter age exerted a significant ($P < .01$) influence on the subjective evaluation scores for l. dorsi muscle color (Table XV, page 57). The color of the l. dorsi muscle from 54 to 59- and over 96-month-old females was scored significantly ($P < .01$) darker than l. dorsi muscle from 3 to 35- and 42 to 47-month-old animals. Three to five-month-old heifers possessed l. dorsi muscle tissue with a significantly ($P < .01$) lighter color than did any other group except the 6 to 11-month-old heifers. The l. dorsi muscle tissue from 54 to 59-month-old females was darker than any other age group, however, this group consisted of only two animals. The least squares constants for the effects of age on l. dorsi muscle color generally indicate darker muscle tissue with advancing animal age (Table XVI). These results substantiate the work of Helser (1930), who reported that muscle tissue from calves was a lighter red color than muscle tissue from older cattle; Simone *et al.* (1959), who found that meat from 30-month-old steers was darker than meat from 18-month-old steers; and Tuma *et al.* (1963), who observed that l. dorsi steaks were darker with advancing slaughter age.

Fat Color

Fat color, as subjectively evaluated with the Munsell Color Paddles, was significantly ($P < .01$) influenced by chronological age in beef females (Table XV, page 57). Females 54 to 59 and over 101 months of age possessed significantly ($P < .01$) darker fat than

TABLE XVI

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON
SELECTED MEAT CHARACTERISTICS

Age group mo.	Marbling score ^a	Fat color ^a	Muscle color ^a	Specific gravity ^b
3-5	-2.77 ^f	-2.90 ^h	-1.61 ^h	0.00559 ^c
6-11	-1.17 ^{d,e,f}	-2.07 ^{g,h}	-1.56 ^{g,h}	0.00475 ^{c,d}
12-17	-1.87 ^{e,f}	-1.99 ^{g,h}	-.89 ^{f,g}	-.00159 ^{d,e}
18-23	-.95 ^{d,e,f}	-1.65 ^{f,g,h}	-.60 ^{e,f}	0.00385 ^{c,d}
24-29	-.16 ^{c,d,e}	-.84 ^{e,f,g}	-.00 ^{d,e}	0.00275 ^{c,d}
30-35	0.51 ^{c,d}	-.88 ^{e,f,g}	-.09 ^{d,e}	-.00069 ^{d,e}
36-41	0.37 ^{c,d}	0.06 ^{d,e}	0.14 ^{c,d}	-.00009 ^{d,e}
42-47	0.11 ^{c,d,e}	-.17 ^{d,e,f,g}	-.26 ^{d,e,f}	0.00220 ^{c,d,e}
48-53	0.33 ^{c,d}	0.19 ^{d,e}	0.13 ^{c,d}	-.00055 ^{d,e}
54-59	0.52 ^{c,d,e}	2.34 ^c	1.08 ^c	0.00037 ^{c,d,e}
60-65	-.11 ^{c,d,e}	1.07 ^{c,d}	0.48 ^{c,d}	0.00050 ^{c,d,e}
66-71	0.10 ^{c,d,e}	0.35 ^{c,d,e}	0.12 ^{c,d,e}	-.00503 ^{d,e}
72-77	0.70 ^{c,d}	0.87 ^{c,d}	0.39 ^{c,d}	-.00096 ^{d,e}
78-83	0.19 ^{c,d,e}	0.02 ^{d,e,f}	0.38 ^{c,d}	0.00102 ^{c,d,e}
84-89	2.18 ^c	0.74 ^{c,d,e}	0.42 ^{c,d}	-.00600 ^e
90-95	1.08 ^{c,d}	2.18 ^{c,d}	0.44 ^{c,d}	-.00243 ^{d,e}
96-101	1.14 ^{c,d}	0.40 ^{c,d,e}	0.78 ^c	-.00409 ^{d,e}
102 and over	-.20 ^{c,d,e}	2.27 ^c	0.66 ^c	0.00041 ^{c,d,e}
Arithmetic mean	4.66	4.37	2.96	1.0611

^aSlaughter age influenced these characteristics at the 0.01 level.

^bSlaughter age influenced this characteristic at the 0.05 level.

^{c,d,e,f,g,h}Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly at the designated level of probability.

did females 78 to 83 and under 53 months of age. Three to five-month-old heifers had significantly ($P < .01$) whiter fat than any of the age groups except the females 6 to 23 months of age. The least squares constants for the effects of slaughter age on fat color indicate that fat color values for females under 48 months of age were below the overall mean except for the 36 to 41-month-old group (Table XVI, page 59). Although the fat color values for females 36 to 41 months of age and females over 47 months of age exceeded the overall mean, values generally did not increase progressively with advancing animal age.

Specific Gravity

The arithmetic mean for specific gravity of the excised l. dorsi muscle from the 9-10-11 rib section was 1.0611. The Knoxville females exhibited the highest average specific gravity (1.0641) and the Ames Plantation females yielded the lowest (1.0579). The mean specific gravity (1.0619) of the excised l. dorsi muscle from the 9-10-11 rib section of the Plateau Station female carcasses was intermediate to the extremes and slightly exceeded the overall mean. Specific gravity was significantly ($P < .05$) influenced by age (Table XV, page 57). However, the least squares constants for the effects of age on specific gravity were irregular and failed to reveal an explicit trend with respect to slaughter age (Table XVI, page 59). The data indicate that specific gravity was more dependent on the per cent ether extract in the l. dorsi muscle than on any other variable. Variation in the per cent ether

extract from the l. dorsi muscle accounted for over 40 per cent of the variation in specific gravity.

IV. PALATABILITY

Shear Tests

Slaughter age exerted a significant ($P < .01$) influence on the Warner-Bratzler shear values for 1-inch diameter cores from the l. dorsi muscle of the boneless 6-7-8 rib roasts (Table XVII). Cores of l. dorsi muscle from females over 101 months of age required significantly ($P < .01$) more force to shear than did cores from females 3 to 11 and 30 to 35 months of age. No significant ($P < .01$) differences in the shear force values were observed between the cores from animals 6 to 101 months of age except the 72 to 77-month-old group. The cores from the roasts representing the 72 to 77-month-old females required significantly ($P < .01$) more force to shear than did the 3 to 5-month-old group. The overall mean for Warner-Bratzler shear force values was 17.4 lb. The least squares constants (Table XVIII) reveal that cores from only the 12 to 17-, 60 to 65-, 72 to 77- and over 95-month-old females required more force to shear than did the cores from the 3 to 5-month-old group. Although the least squares constants are negative for the effect of slaughter age on the shear force values of cores from 84 to 95-month-old females, the pattern of the constants suggests a slight increase in shear force values with advancing animal age. These results support the work of Mackintosh et al. (1936) and Brady (1937) who reported that meat from yearling steers required less force

TABLE XVII
ANALYSIS OF VARIANCE FOR THE EFFECTS OF AGE ON
MEASURES OF BEEF PALATABILITY

Source	d.f.	Mean square			
		Shear value	Sensory panel tenderness	Sensory panel juiciness	Sensory panel flavor
Age	17	20.2754**	5.0935**	0.7306*	0.3916**
Residual	118	7.3862	1.0356	0.3738	0.1650

*P < .05.

**P < .01.

TABLE XVIII

LEAST SQUARES CONSTANTS FOR THE EFFECTS OF AGE ON
MEASURES OF BEEF PALATABILITY

Age group mo.	Shear values ^a	Sensory panel tenderness scores ^a	Sensory panel juiciness scores ^b	Sensory panel flavor scores ^a
3-5	-3.61 ^f	1.97 ^c	-.82	-.63 ^c
6-11	-3.36 ^{e,f}	1.77 ^{c,d}	-.56	-.10 ^{c,d}
12-17	1.73 ^{c,d,e}	-.11 ^{d,e,f}	-.04 ^e	-.30 ^{c,d}
18-23	0.16 ^{c,d,e,f}	0.28 ^{d,e,f}	-.02 ^e	-.03 ^{c,d}
24-29	-.12 ^{c,d,e,f}	0.15 ^{d,e,f}	-.01 ^e	0.09 ^d
30-35	-1.37 ^{d,e,f}	0.86 ^{c,d,e}	0.32 ^c	0.25 ^{c,d}
36-41	-.67 ^{c,d,e,f}	0.41 ^{d,e,f}	0.23 ^c	0.00 ^d
42-47	0.34 ^{c,d,e,f}	-.16 ^{e,f}	-.10 ^e	0.20 ^{c,d}
48-53	0.08 ^{c,d,e,f}	-.35 ^{e,f}	0.03 ^{d,e}	-.02 ^{c,d}
54-59	0.48 ^{c,d,e,f}	-.55 ^{e,f}	0.38 ^c	0.25 ^{c,d}
60-65	0.98 ^{c,d,e}	-.27 ^{e,f}	0.13 ^{c,d,e}	0.05 ^{c,d}
66-71	0.01 ^{c,d,e,f}	0.04 ^{d,e,f}	-.08 ^e	0.16 ^{c,d}
72-77	2.36 ^{c,d}	-.82 ^f	0.10 ^{c,d,e}	0.09 ^{c,d}
78-83	0.23 ^{c,d,e,f}	0.17 ^{d,e,f}	0.06 ^{c,d,e}	0.11 ^{c,d}
84-89	-.05 ^{c,d,e,f}	-.79 ^{e,f}	-.14 ^e	-.11 ^{c,d}
90-95	-.89 ^{c,d,e,f}	-1.33 ^f	0.24 ^{c,d}	0.05 ^{c,d}
96-101	1.30 ^{c,d,e}	-.46 ^{e,f}	0.32 ^c	0.09 ^{c,d}
102 and over	2.38 ^c	-.83 ^f	-.05 ^e	-.16 ^{c,d}
Arithmetic mean	17.44	6.63	6.98	7.23

^aSlaughter age influenced this characteristic at the 0.01 level.

^bSlaughter age influenced this characteristic at the 0.05 level.

^{c,d,e,f} Constants within a column bearing the same superscript letter do not differ significantly. All others differ significantly at the designated levels of probability.

to shear than did meat from more mature cattle. However, the results disagree with the work of Lowe and Kastelic (1961) who observed that slaughter age of the animal did not influence shear force values of samples from animals ranging from 6 to 42 months of age. Tuma et al. (1962b) observed that shear force values for samples of 1. dorsi muscle increased significantly with animal age when 18-, 42- and 90-month-old Hereford females were compared. These workers also noted a greater change in the shear force values of 1. dorsi muscle samples between the 18- and 42-month-old females than between the 42- and 90-month-old females. Thus, they hypothesized that animal age may exert a greater influence on beef tenderness at a point between 18 and 42 months than between 42 and 90 months of age. However, a careful review of the least squares constants for the effects of age on tenderness as measured by shear force values of 1. dorsi muscle (Table XVIII, page 63) reveals that only small differences existed between the shear values of cores from 18 to 23- and 42 to 47-month-old females. On the other hand, the 1. dorsi muscle cores from the 90 to 95-month-old animals required less force to shear than did comparable samples of 18 to 23- and 42 to 47-month-old females. The least squares constants indicate that changes in shear values of 1. dorsi muscle samples from animals between 18 and 47 months of age were only slight. The most noticeable positive change in the shear force value of 1. dorsi samples occurred between samples from 3 to 5- and 12 to 17-month-old females. Thus, a critical period with regard to shear tenderness may be between 3 and 17 months of age. Considering that samples from the 12 to 17-month-old

animals were the least tender of any age group between 3 and 71 months of age, these results suggest that yearling cattle possibly are being slaughtered in a chronological age period when they are the least tender. These results do not substantiate the work of Tuma et al. (1963) who reported higher shear force values for l. dorsi muscle samples from 6-month-old animals than from 18-month-old animals.

Sensory Panel Tenderness Scores

Sensory panel tenderness scores for l. dorsi muscle from the cooked 6-7-8 rib boneless roasts were significantly ($P < .01$) influenced by slaughter age (Table XVII, page 62). The roasts from the 3 to 5-month-old heifers were scored significantly ($P < .01$) more tender than the roasts from all other age groups except the roasts representing the 6 to 11- and 30 to 35-month-old females. Differences in sensory panel tenderness scores for roasts from females 12 to 29 and over 35 months of age were not significant ($P < .01$). The least squares constants for the effect of age on sensory panel tenderness scores (Table XVIII, page 63) indicate that 90 to 95-month-old females were the least tender of all groups, yet the panel scored the tenderness of the roasts from this group better than "fair." The results of this study support the work of Nelson et al. (1930) who reported no significant difference in the sensory panel tenderness scores for beef from calves, yearlings and two-year-old animals. Simone et al. (1959) observed that a sensory panel preferred the tenderness of meat from 18-month-old steers to meat from 30-month-old steers. However, the results of the study

reported herein indicate that an experienced sensory panel scored roasts from 30 to 35-month-old females slightly more tender than roasts from 18 to 23-month-old females. These results do not completely substantiate the work of Tuma et al. (1962b) who found that sensory panel tenderness scores for broiled l. dorsi steaks decreased significantly with advancing age in 18-, 42- and 90-month-old Hereford females. Although the results reported herein indicate that the differences in sensory panel tenderness scores for l. dorsi samples from 18 to 23-, 42 and 47- and 90 to 95-month-old females were not significant ($P < .01$), the least squares constants indicate a general decrease in tenderness with advancing age among the three groups. A critical review of the constants reveals that these results disagree with the ideas of Tuma et al. (1962b) and Tuma et al. (1963) who hypothesized that slaughter age may exert a greater influence on tenderness between 18 and 42 months than during the period between 42 and 90 months of age. The current results indicate more change in sensory panel tenderness scores for l. dorsi samples between the 42 to 47- and 90 to 95-month-old females than for comparable samples from females between the ages of 18 to 23 and 42 to 47 months old. However, it should be acknowledged that both studies by Tuma et al. (1962b and 1963) involved the evaluation of broiled l. dorsi steaks from the short loin, whereas, roasted l. dorsi samples from the 6-7-8 rib section were used in the current study. A comparative evaluation of the least squares constants for the effect of age on shear value and sensory panel tenderness score (Table XVIII, page 63) indicates that both

measures of tenderness follow a similar pattern on samples representing animals from 3 to 83 months of age.

Sensory Panel Juiciness Scores

Sensory panel scores for juiciness of the roasted l. dorsi muscle samples from the 6-7-8 rib roast were significantly ($P < .05$) influenced by slaughter age (Table XVII, page 62). Roasts from 3 to 11-month-old females had significantly ($P < .05$) less juice than roasts from any of the other age groups. Roasts from 30 to 35-, 54 to 59- and 96 to 101-month-old females were scored significantly ($P < .05$) higher for juiciness by the sensory panel than any other age groups, but the scores for these age groups were not significantly ($P < .05$) different. Roasts from 30 to 35-month-old females received significantly ($P < .05$) higher sensory panel juiciness scores than roasts from 18 to 23-month-old females. These results disagree with the work of Simone et al. (1959) who observed no significant difference in juiciness scores of rib roasts from 18- and 30-month-old steers. Work by Tuma et al. (1962b) revealed no significant difference in sensory panel juiciness scores for l. dorsi steaks from 18-, 42- and 90-month-old Hereford females. However, the results reported herein showed that roasts from 90 to 95-month-old females were scored significantly ($P < .05$) more juicy than comparable samples from 18 to 23- and 42 to 47-month-old females which were not significantly ($P < .05$) different. The least squares constants for the effects of slaughter age on sensory panel juiciness scores (Table XVIII, page 63) exhibit a slight but indistinct trend toward increased juiciness with advanced animal age.

Sensory Panel Flavor Scores

Sensory panel flavor scores were significantly ($P < .01$) influenced by the age of beef females (Table XVII, page 62). Roasted l. dorsi muscle samples from 3 to 5-month-old females received the lowest average sensory panel flavor score. However, the flavor score of the 3 to 5-month-old group was not significantly ($P < .01$) different from other age groups except the 24 to 29- and 36 to 41-month-old females. Differences in sensory panel flavor scores for roasts from all age groups over 5 months of age were not significant ($P < .01$). Although roasts from the 3 to 5-month-old females received the lowest average sensory panel flavor score, it should be noted that the sensory panel was not overly critical of the roasts from the young cattle and scored the flavor of these roasts slightly less than "good." These results indicate that the sensory panel either did not detect or was not critical of the blandness often associated with meat from very young cattle. These results generally support the work of Tuma et al. (1962b) and Tuma et al. (1963) who found no significant difference in sensory panel flavor scores for l. dorsi steaks from cattle 6, 18, 42 and 90 months of age. The least squares constants for the effects of age on sensory panel flavor scores failed to exhibit a particular trend in flavor with respect to animal age (Table XVIII, page 63). The influence of age on selected indices of meat palatability is shown in Figure 5.

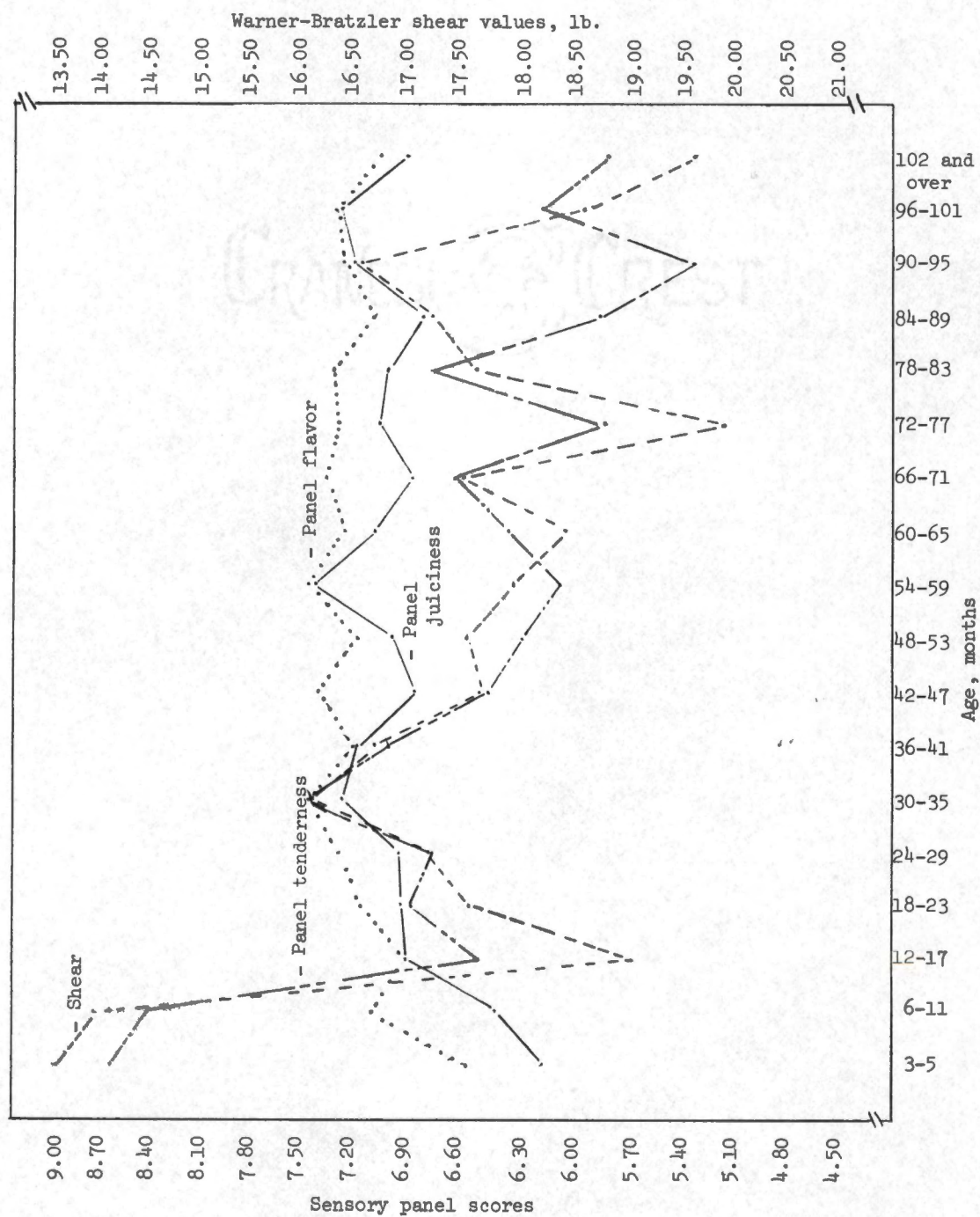


Figure 5. Influence of age on shear values and sensory panel scores for tenderness, juiciness and flavor.

V. CORRELATION AMONG TRAITS

General Characteristics

The simple correlation coefficients calculated on a within-location basis among all traits studied are presented in Table XIX.

Slaughter age was significantly ($P < .01$) associated with slaughter weight and hot carcass weight ($r = 0.60$ and $r = 0.76$, respectively). The association between hot carcass weight and the weight of the rib cuts (6-12 rib weight, $r = 0.96$ and 9-10-11 rib section, $r = 0.95$) indicated that increases in carcass weight were accompanied by proportional increases in the weight of each rib cut. The variation in age accounted for approximately 61 per cent of the variation in carcass length. Carcass length was significantly ($P < .01$) related to the weights of the 6-12 rib cut and the 9-10-11 rib section ($r = 0.82$ and $r = 0.78$, respectively).

The positive association ($r = 0.81$) between chronological age and the subjective evaluation of physiological age (maturity score) indicated that age variation accounted for over 65 per cent of the variation in maturity score. These results are higher than the results of work cited by Briskey and Bray (1964). After an intensive review of the literature pertaining to the association between chronological age in beef animals and physiological age in subsequent beef carcasses, Briskey and Bray (1964) reported that only 10 to 40 per cent of the variation in carcass maturity was accounted for by variation in actual chronological age. A probable explanation for the higher percentage

	32	31	30	9 ^c	8	7 ^c	6	5	4	3 ^c	2
1 Slaughter age, mo.	-.21	0.60	0.71	0.78	0.42	0.56	-.69	0.31	0.81	0.76	0.60
2 Slaughter weight, lb.	-.36	0.63	0.61	0.94	0.56	0.68	-.48	0.58	0.75	0.97	
3 Hot carcass weight, lb. ^c	-.44	0.43	0.42	0.87	0.77	0.75	-.42	0.50	0.76		
4 Maturity	-.31	0.69	0.73	0.82	0.48	0.52	-.82	0.43			
5 Marbling score	-.56	0.28	0.30	0.35	0.60	0.34	-.03				
6 Carcass grade	0.11	-.58	-.64	-0.56	-.19	-.24					
7 <u>L. dorsi</u> area, sq. in. ^c	-.48	0.22	0.29	0.57	0.49						
8 Fat thickness, mm.	-.44	0.33	0.26	0.59							
9 Carcass length, in. ^c	-.26	0.57	0.49	0							
10 6-12 rib weight, lb.	-.45	0.61	0.56	0							
11 9-10-11 rib weight, lb.	-.46	0.59	0.54	0							
12 9-10-11 rib separable muscle, %	0.37	-.27	-.17	-							
13 9-10-11 rib separable fat, %	-.45	0.28	0.18	0							
14 9-10-11 rib separable bone, %	0.39	-.03	0.07	-							
15 9-10-11 rib protein, %	0.43	-.29	-.23	-							
16 9-10-11 rib ether extract, %	-.50	0.37	0.25	0							
17 9-10-11 rib moisture, %	0.48	-.38	-.25	-							
18 Daily gain, lb. ^c	-.01	0.33	0.37	0							
19 9-10-11 rib <u>l. dorsi</u> muscle weight, gm.	-.40	0.61	0.55	0							
20 9-10-11 rib <u>l. dorsi</u> protein, %	0.07	0.09	0.01	-							
21 9-10-11 rib <u>l. dorsi</u> ether extract, %	-.64	0.25	0.28	0							
22 9-10-11 rib <u>l. dorsi</u> moisture, %	0.59	-.30	-.27	-							
23 Shear value	0.06	0.38	0.37	-							
24 Drip loss, %	-.48	0.21	0.26	0							
25 Evaporation loss, %	0.21	0.23	0.33	-							
26 Total loss, %	-.17	0.34	0.46	0							
27 Sensory panel tenderness score	0.11	-.51	-.55	0							
28 Sensory panel juiciness score	-.29	0.24	0.19	0							
29 Sensory panel flavor score	-.05	0.19	0.11								
30 Fat color	-.19	0.64									
31 Muscle color	-.09										
32 Specific gravity											

^aCalculated on a within-location basis.

^bAll correlation coefficients are based on significance at the 0.05 and 0.01 levels of probability.

^cCorrelation coefficients based on 59 animals.

of the variation in maturity being accounted for by chronological age variation in the current study involves the wider range of chronological ages (3 to 211 months of age) and subsequently a more extended range in maturity scores (veal to F maturity).

The association between carcass maturity score and carcass quality grade was negative ($r = -.82$) and significant ($P < .01$), emphasizing the depressing role played by maturity in the U.S.D.A. beef quality grading standards. The negative correlation ($P < .01$) between chronological age and carcass quality grade ($r = -.69$) emphasizes the depressing effect of age on quality grade.

The association ($P < .01$) between age and fat thickness over the 1. dorsi muscle ($r = 0.42$) was positive indicating that increased animal age generally was accompanied by increased fat thickness. However, variation in age accounted for only 17.6 per cent of the variation in fat thickness over the 1. dorsi muscle. This suggests that fat thickness did not increase progressively with increased animal age. Fat thickness was positively associated with the weights of the rib cuts (6-12 rib cut, $r = 0.74$ and 9-10-11 rib cut, $r = 0.76$). These results indicate that approximately 55 per cent of the variation in the weights of rib cuts, representing animals of varying chronological age, can be accounted for by variation in fat thickness over the 1. dorsi muscle at the 12th rib. These relationships are slightly higher than comparable correlations reported by Williams (1965), who found a positive association ($r = 0.61$) between fat thickness and both the weight of the 6-12 rib cut and the weight of the 9-10-11 rib cut when comparing bulls, heifers and steers of similar chronological age.

Physical Composition of the 9-10-11 Rib Section

Slaughter age was significantly ($P < .01$) correlated ($r = -.28$) with the percentage yield of muscle from the 9-10-11 rib section. However, maturity score was more highly associated ($r = -.35$) with the yield of separable muscle from the 9-10-11 rib section than was chronological age. The association ($r = -.49$) between marbling score and yield of separable muscle was negative ($P < .01$). The percentage yield of separable muscle from the 9-10-11 rib section was negatively correlated ($r = -.60$) with fat thickness over the 1. dorsi muscle at the 12th rib. These results demonstrate an inverse relationship between measures of fat content and yield of separable muscle. The percentage yield of separable fat from the 9-10-11 rib section was positively correlated ($P < .01$) with age ($r = 0.32$) and maturity ($r = 0.38$). Variations in fat thickness over the 1. dorsi muscle at the 12th rib accounted for over 53 per cent of the variation in yield of separable fat from the 9-10-11 rib section. The weight of the 9-10-11 rib section was highly associated with the percentage yield of separable fat ($r = 0.77$), muscle ($r = -.62$) and bone ($r = -.53$) from the 9-10-11 rib section. This suggests that increases in 9-10-11 rib cut weight were largely a function of increased fat deposition as animals increased in age and that the muscle and bone percentage of the cut decreased with increases in rib cut weight when animals of widely varying ages were compared.

The percentage yield of separable bone from the 9-10-11 rib section was not significantly ($P < .05$) correlated with age or maturity.

However, the percentage yield of separable bone was negatively correlated ($P < .01$) with fat thickness ($r = -.62$) and percentage yield of separable fat from the 9-10-11 rib section ($r = -.66$). On the other hand, the association ($P < .01$) between separable bone yield and percentage separable muscle from the 9-10-11 rib section ($r = 0.41$) was positive.

Chemical Composition of the Boneless Portion of the 9-10-11 Rib Section

The crude protein content of the boneless portion of the 9-10-11 rib section was negatively associated ($P < .01$) with age ($r = -.33$) and maturity ($r = -.44$). The moisture content of the boneless portion of the 9-10-11 rib section was negatively correlated with both chronological age ($r = -.38$) and maturity ($r = -.48$). However, both age and maturity were positively associated ($P < .01$) with the ether extract content of the boneless portion of the 9-10-11 rib section ($r = 0.38$ and $r = 0.48$, respectively).

Fat thickness was significantly ($P < .01$) correlated with the major chemical components of the boneless portion of the 9-10-11 rib section (moisture, $r = -.78$; crude protein, $r = -.69$ and ether extract, $r = 0.78$). These results suggest that fat thickness over the 1. dorsi muscle could be utilized as an indicator of the chemical composition of the boneless portion of the 9-10-11 rib section.

The percentage yield of separable muscle from the 9-10-11 rib section was correlated with the content of the major chemical components of the boneless portion of the 9-10-11 rib section (crude protein, $r = 0.74$; moisture, $r = 0.77$ and ether extract, $r = -.79$). The variation

in the percentage yield of separable bone from the 9-10-11 rib section accounted for over 32 per cent of the variation in crude protein content, approximately 41 per cent of the variation in moisture content, and over 43 per cent of the variation in the ether extract content of the boneless portion of the 9-10-11 rib section. The content of the major chemical components of the boneless 9-10-11 section were significantly ($P < .01$) associated with the percentage yield of separable fat from the cut (crude protein, $r = -.74$; moisture, $r = -.91$ and ether extract, $r = 0.90$). These results suggest that the separable fat yield of the 9-10-11 rib cut could serve as an appropriate indicator of ether extract content, moisture content and to a smaller degree the crude protein content of the boneless portion of the 9-10-11 rib section.

The ether extract content of the boneless portion of the 9-10-11 rib section was highly related to the crude protein content ($r = -.84$) and the moisture content ($r = -.99$) of the same carcass portion. These results substantiate the work of Hankins and Howe (1946), who reported that the ether extract content of the boneless portion of the 9-10-11 rib section was highly correlated with the protein ($r = -.93$) and moisture ($r = -.99$) content of the carcass.

Weight of the Excised L. Dorsi Muscle from the 9-10-11 Rib Section

The weight of the excised l. dorsi muscle from the 9-10-11 rib section was significantly ($P < .01$) associated with chronological age ($r = 0.61$), carcass maturity ($r = 0.73$), carcass length ($r = 0.78$), hot carcass weight ($r = 0.92$) and 9-10-11 rib section weight ($r = 0.91$).

These results indicated increases in l. dorsi weight were proportional to increases in measures of age and to increases in selected indices of carcass dimension. The weight of the excised l. dorsi muscle from the 9-10-11 rib section was positively correlated with marbling ($r = 0.56$), fat thickness ($r = 0.58$), per cent separable fat from the 9-10-11 rib section ($r = 0.57$), ether extract content of the boneless portion of the 9-10-11 rib section ($r = 0.65$) and the ether extract content of the excised l. dorsi muscle ($r = 0.61$). However, the per cent moisture content of the boneless portion of the 9-10-11 rib section, the percent separable muscle from the 9-10-11 rib section, and the per cent moisture content of the excised l. dorsi muscle were negatively correlated with the weight of the excised l. dorsi muscle from the 9-10-11 rib section ($r = -.66$, $r = -.45$ and $r = -.64$, respectively). These results indicate that the increased weight of the excised l. dorsi muscle was due largely to increased fat content.

Chemical Composition of the Excised L. Dorsi Muscle from the 9-10-11 Rib Section

Slaughter age was significantly ($P < .01$) correlated with the percentage moisture content ($r = -.40$) and the percentage ether extract content ($r = 0.36$) of the excised l. dorsi muscle from the 9-10-11 rib section. However, maturity was more highly associated with the moisture content ($r = -.47$) and ether extract content ($r = 0.44$) of the excised l. dorsi muscle than was age. The per cent moisture content of the l. dorsi was negatively associated with the prominent indices of carcass

composition (fat thickness, $r = -.74$; 9-10-11 rib section weight, $r = -.75$; per cent separable fat from the 9-10-11 rib section, $r = -.75$ and the per cent ether extract content of the boneless portion of the 9-10-11 rib section, $r = -.80$); whereas, the per cent ether extract content of the l. dorsi muscle was positively related to the same indices of composition ($r = 0.69$, $r = 0.71$, $r = 0.69$ and $r = 0.74$, respectively). The variation in per cent ether extract content of the l. dorsi muscle accounted for approximately 88 per cent of the variation in the per cent moisture content of the l. dorsi muscle. These results indicate that a slightly higher correlation exists between the ether extract and moisture content of the l. dorsi muscle than reported by Romans et al. (1965a), who found a correlation coefficient of $-.81$ between the ether extract and moisture content of the l. dorsi muscle samples representing 4 maturity levels (A, B, C and D). A possible explanation for the differences between the l. dorsi muscle ether extract and moisture content relationship reported by Romans et al. (1965a) and the correlation found in the current study involves differences in the maturity level ranges included in each study. The work of Romans et al. (1965a) involved only 4 maturity levels (A, B, C and D), whereas, all maturity levels (veal through F) were included in the current study.

Romans et al. (1965a) found a significant ($P < .01$) correlation between per cent fat and per cent protein ($r = -.32$), and a low, non-significant relationship between per cent moisture and per cent protein in the l. dorsi muscle. However, the results of the current study reveal that crude protein content of l. dorsi muscle was not

significantly ($P < .05$) associated with animal age, carcass maturity, per cent moisture content or per cent ether extract from the 1. dorsi muscle. Considering the lack of association between per cent crude protein and the per cent ether extract or the per cent moisture content of the 1. dorsi muscle plus the significant association between the ether extract and moisture content of the same muscle, these results suggest that knowledge of either the ether extract or moisture content could be utilized as a predictor of the per cent content of the other component.

Cooking Losses of the Boneless 6-7-8 Rib Roasts

Slaughter age was significantly ($P < .01$) associated with all three measures of cooking losses (per cent drip loss, $r = 0.41$; per cent evaporation loss, $r = 0.25$ and per cent total losses, $r = 0.50$). Also the selected measures of cooking losses were correlated with carcass maturity (per cent drip loss, $r = 0.50$; per cent evaporation loss, $r = 0.25$ and per cent total loss, $r = 0.56$). The per cent drip loss was positively associated with selected indices of fat content (fat thickness, $r = 0.70$; 9-10-11 rib section per cent separable fat, $r = 0.71$; ether extract content of the boneless portion of the 9-10-11 rib section, $r = 0.76$ and the ether extract content of the 1. dorsi muscle, $r = 0.62$). On the other hand, per cent drip loss was negatively associated with per cent separable muscle from the 9-10-11 rib section ($r = -.54$), the per cent moisture content of the boneless portion of the 9-10-11 rib section ($r = -.76$) and the per cent moisture content

of the excised 1. dorsi muscle from the 9-10-11 rib section ($r = -.63$). These results indicate that drip losses were influenced by the fat content of roasts and that a major portion of the drip losses was fat. These results substantiate the work of Backus (1958), who found that the drip loss from boneless 6-7-8 rib roasts was directly associated with the degree of fatness.

Evaporation loss was positively associated with the per cent separable muscle from the 9-10-11 rib section ($r = 0.36$) and per cent moisture content of the boneless portion of the 9-10-11 rib section ($r = 0.37$), but negatively related to selected indices of fatness (fat thickness, $r = -.24$; per cent separable fat from the 9-10-11 rib section, $r = -.42$ and per cent ether extract content of the boneless portion of the 9-10-11 rib section, $r = -.38$). This indicates that the evaporation loss was inversely related to fatness and generally represented a loss of moisture from the muscle portion of the respective roast.

The per cent total loss during the cooking period was positively ($P < .01$) related to the more specific measures of cooking loss (per cent drip loss, $r = 0.58$ and per cent evaporation loss, $r = 0.72$). Since the variation in evaporation loss accounted for over 51 per cent of the variation in total cooking loss and the variation in drip loss accounted for less than 34 per cent of the variation in total loss, these results indicate that evaporation loss was a more appropriate predictor of total loss than was drip loss.

Marbling Score

Marbling score was significantly ($P < .01$) associated with slaughter age ($r = 0.31$) and carcass maturity ($r = 0.43$). These results substantiate the work of Harwin et al. (1961) who reported a positive association ($r = 0.32$) between marbling score and slaughter age in yearling steers. Marbling score was positively correlated with selected physical measures of carcass fatness (fat thickness, $r = 0.60$ and per cent separable fat from the 9-10-11 rib section, $r = 0.61$), and variation in the weight of the 9-10-11 rib section accounted for over 42 per cent of the variation in marbling score. The ether extract content of the l. dorsi muscle was positively associated with marbling score ($r = 0.85$), however, the moisture content of the l. dorsi muscle was negatively correlated with marbling score ($r = -.79$). These results agree with the work of Romans et al. (1965a) who observed that marbling was closely related to the fat and moisture content of the l. dorsi muscle. The relationship ($r = -.21$) between the crude protein content of the l. dorsi muscle and marbling score was low yet significant ($P < .05$). These results suggest that persons who are on a high protein, low fat diet should eat beef with only minute amounts of marbling.

Muscle and Fat Color

Muscle color was significantly ($P < .01$) associated with slaughter age ($r = 0.60$) and carcass maturity ($r = 0.69$). Muscle color was positively correlated with fat color ($r = 0.64$), but negatively associated with carcass grade ($r = -.58$). These results indicate a

darkening of muscle tissue with advancing animal age and/or advancing carcass maturity. Considering that approximately 47 per cent of the variation in maturity was associated with the variation in muscle color, these results generally support the use of muscle color in the evaluation of carcass maturity by Federal Graders. Fat color, as evaluated with the Munsell Color Paddles, was positively ($P < .01$) correlated with slaughter age ($r = 0.71$) and carcass maturity ($r = 0.73$), but negatively associated with carcass grade ($r = -.64$). These results indicate that fat tissue tends to become more yellow with increasing age or maturity.

Specific Gravity

The specific gravity of the excised l. dorsi muscle from the 9-10-11 rib section was significantly ($P < .01$) associated with slaughter age ($r = -.21$) and maturity ($r = -.31$). However, only a small per cent of the variation in specific gravity was accounted for by variation in slaughter age (4.4) or maturity (9.6). Specific gravity was negatively correlated with marbling ($r = -.56$) and per cent ether extract in the l. dorsi muscle ($r = -.64$), but positively associated with the per cent moisture content of the l. dorsi muscle ($r = 0.59$). These results indicate that an increase in per cent fat content or a decrease in the per cent moisture content of the l. dorsi muscle was accompanied by a lower specific gravity value. However, these relationships do not establish specific gravity as an appropriate predictor of l. dorsi muscle composition.

Shear Tests

Warner-Bratzler shear force values were positively correlated ($P < .01$) with slaughter age ($r = 0.34$) and carcass maturity ($r = 0.33$). Although these relationships were significant, the variation in either age or maturity level accounted for only 10.8 to 11.6 per cent of the variation in shear force values. The simple partial regression coefficients (Table XX) between shear value and chronological age ($b' = 0.38$) and maturity level ($b' = 0.41$), on a marbling constant basis, are higher than the simple correlations among the same variables. These results generally agree with the work of Palmer (1963) and Alsmeyer *et al.* (1959), who reported positive and significant correlations between animal age and Warner-Bratzler shear force values ($r = 0.27$ and $r = 0.24$, respectively). However, the results do not substantiate the work of Romans *et al.* (1965a), who reported no significant association between carcass maturity and shear force value when comparing 4 levels of maturity (A, B, C and D). Shear force value was positively correlated with both fat color ($r = 0.37$) and muscle color ($r = 0.38$). These results suggest that muscle or fat color was comparable to age or maturity as an indicator of tenderness.

The correlation between carcass grade and shear force value ($r = -.34$) was significant ($P < .01$) and negative. However, variation in carcass quality grade accounted for less than 12 per cent of the variation in shear force value, leaving more than 88 per cent of the variation in shear force value dependent on other factors. The variation in shear force values accounted for over 60 per cent of the variation

TABLE XX

SIMPLE CORRELATION COEFFICIENTS AND STANDARD PARTIAL REGRESSION
COEFFICIENTS OF AGE, MARBLING AND MATURITY WITH SHEAR
VALUE, SENSORY PANEL TENDERNESS SCORES, SENSORY
PANEL JUICINESS SCORES AND SENSORY
PANEL FLAVOR SCORES

Y	r^a or b'	X			
		Shear value	Sensory panel tenderness scores	Sensory panel juiciness scores	Sensory panel flavor scores
Chronological age	r	0.34	-.46	0.17	0.11
	b'^b	0.38	-.47	0.02	0.00
Marbling score	r	-.01	-.13	0.48	0.36
	b'^c	-.13	0.01	0.48	0.36
Maturity score	r	0.33	-.49	0.27	0.23
	b'^d	0.41	-.53	0.07	0.10

^aSimple correlation coefficients; $P < .05 = 0.17$ and $P < .01 = 0.22$.

^bStandard partial regression coefficients with marbling held constant.

^cStandard partial regression coefficients with chronological age held constant.

^dStandard partial regression coefficients with marbling held constant.

in panel tenderness scores which indicates that the shear device is an appropriate criterion for evaluating beef tenderness.

A non-significant correlation between marbling score and shear force value ($r = -.01$) suggests that marbling is not an appropriate indicator of meat tenderness. The inappropriateness of marbling in tenderness evaluation is further shown by the low standard partial regression coefficient of marbling with shear value ($b' = -.13$), when chronological age was held constant. These results indicate that marbling probably is overemphasized in the evaluation of beef carcass quality. The findings of this study generally substantiate the work of Goll et al. (1965), who reported that marbling content did not appear to be associated with beef tenderness as measured by shear tests.

Sensory Panel Tenderness Scores

Sensory panel tenderness scores were negatively associated ($P < .01$) with slaughter age ($r = -.46$), slaughter weight ($r = -.49$) and maturity ($r = -.49$). These relationships indicate that both chronological and physiological age generally have an adverse influence on beef tenderness, yet relatively small portions of the variation in sensory panel tenderness score were accounted for by either age (21.2 per cent) or maturity (24.0 per cent). The standard partial regression coefficients of age ($b' = 0.47$) and maturity ($b' = -.53$) with sensory panel tenderness scores, as evaluated on a marbling constant basis, show only slight increases in association over the

simple correlation coefficients among the same factors. These results indicate a higher association between age and panel tenderness score than found by Alsmeyer et al. (1959) who reported a correlation coefficient of -0.28 between panel tenderness score and age when comparing 281 animals ranging from 5 to 87 months of age.

The relationships between sensory panel tenderness score and measures of the chemical composition of the 1. dorsi muscle were low but significant (crude protein, $r = -0.22$; ether extract, $r = -0.23$ and moisture $r = 0.28$). The sensory panel tenderness scores were negatively associated ($P < .01$) with fat color ($r = -0.55$) and muscle color ($r = -0.51$). Although only 26 to 30 per cent of the variation in panel tenderness scores was accounted for by variation in the subjective color evaluation scores, these results indicate that muscle and fat colors may be utilized as possible criteria in beef palatability evaluation. However, the fat and muscle color association with age and maturity should be considered when utilizing muscle and fat color values as predictors of meat tenderness.

A correlation coefficient of -0.13 between sensory panel tenderness score and marbling score indicates that marbling is of questionable value in meat tenderness evaluation. This idea is substantiated by an age constant standard partial regression coefficient of 0.01 between marbling score and sensory panel tenderness score. These results do not substantiate the work of Alsmeyer et al. (1959), who found that marbling and panel tenderness scores were positively ($P < .01$) correlated ($r = 0.26$) when animal age was held constant.

Sensory Panel Juiciness Scores

Slaughter age was positively ($P < .05$) associated with sensory panel juiciness scores ($r = 0.17$). However, sensory panel juiciness scores were more highly related ($P < .01$) to slaughter weight ($r = 0.33$) and carcass maturity ($r = 0.27$). Marbling constant standard partial regression coefficients of age ($b' = 0.02$) and maturity level ($b' = 0.07$) with sensory panel juiciness scores fail to indicate an association between chronological age or maturity and meat juiciness. Sensory panel juiciness scores were correlated with the ether extract ($r = 0.37$) and moisture content of the 1. dorsi muscle ($r = -.34$) and the per cent separable fat from the 9-10-11 rib section ($r = 0.32$). These results indicate that increased fat content of the 1. dorsi muscle was accompanied by a more desirable panel juiciness score. The simple correlation between panel juiciness score and marbling ($r = 0.48$) was comparable to the age constant standard partial regression coefficient of marbling with panel juiciness score ($b' = 0.48$). These results indicate that 23 per cent of the variation in the panel juiciness scores was accounted by variation in marbling score and that the influence of marbling score on panel juiciness score is independent of chronological age.

Sensory panel juiciness scores showed a negative correlation with the specific gravity of the excised 1. dorsi muscle from the 9-10-11 rib section ($r = -.29$). Although the correlation coefficient is slightly smaller, these results agree with the work of Backus (1958), who reported a negative association between the specific gravity of the

excised 1. dorsi muscle portion and the sensory panel juiciness score.

Sensory Panel Flavor Scores

Sensory panel flavor scores were not significantly ($P < .05$) related to age, but were significantly ($P < .01$) associated with slaughter weight ($r = 0.34$) and maturity ($r = 0.23$). As noted in the panel juiciness scores, sensory panel flavor scores were positively correlated with selected indices of fat content (ether extract content of the boneless portion of the 9-10-11 rib section, $r = 0.32$; per cent separable fat from the 9-10-11 rib section, $r = 0.26$ and ether extract content of the excised 1. dorsi muscle portion, $r = 0.28$). Although these correlations are not high, they suggest that beef flavor is partially dependent on the fat content. Panel flavor scores were significantly ($P < .01$) associated with marbling ($r = 0.36$) and panel juiciness scores ($r = 0.40$). An evaluation on an age constant basis did not alter the association between marbling score and panel flavor score. This suggests that the variation in beef flavor accounted for by marbling score was independent of variation in chronological age. The positive association of marbling and panel juiciness score with panel flavor scores indicates that increased fat and/or moisture content of 1. dorsi roasts would be complimented by higher panel flavor scores. However, a fat content level probably exists at which point the sensory panel would be critical of the excessive fat content.

CHAPTER V

SUMMARY

The wholesale ribs from the left sides of 138 carcasses of Angus and Hereford females were used to study the influence of chronological and physiological age on carcass composition, meat characteristics and palatability. The females represented three of the beef cattle breeding herds (Ames Plantation, Crossville and Knoxville) of the University of Tennessee. Slaughter age ranged from 3 to 211 months with a mean of 50 months. The mean carcass maturity level was C+ and ranged from veal to F. A correlation coefficient of 0.81 existed between chronological age and maturity level.

A physical separation of the 9-10-11 rib section was conducted to examine possible differences in the physical composition of the carcasses. Age significantly influenced per cent separable muscle and separable fat, but not per cent separable bone of the 9-10-11 rib section. A positive correlation was found between slaughter age and separable fat ($r = 0.32$), whereas, the association between age and separable muscle ($r = -.28$) was negative. A proximate analysis was conducted on samples of blended boneless tissue from the 9-10-11 rib section and the excised l. dorsi muscle of the same cut of each carcass. The chemical composition of the boneless tissue samples was significantly influenced by slaughter age. Slaughter age was significantly associated with per cent ether extract ($r = 0.36$) and per cent moisture content ($r = -.40$) of the l. dorsi muscle, but the association between age and

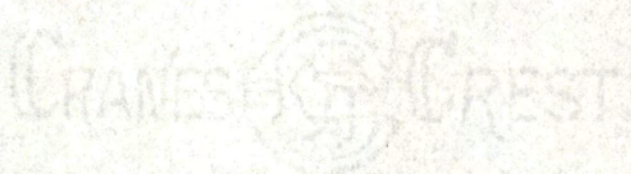
per cent crude protein was not significant.

Cooking studies were conducted on boneless 6-7-8 rib roasts to evaluate the effects of age on cooking losses. Slaughter age significantly influenced the per cent drip and total losses, but did not exert a significant influence on the per cent evaporation losses. Drip losses were highly related to measures of fat content (ether extract of the boneless tissue of the 9-10-11 rib section, $r = 0.76$ and fat thickness over the 1. dorsi muscle, $r = 0.70$) indicating that increased fat content of roasts was accompanied by increased drip loss.

Warner-Bratzler shear values, objective measures of tenderness, were significantly influenced by chronological age. One-inch cores from the 1. dorsi muscle of 6-7-8 rib roasts from 3 to 5-month-old females sheared significantly more tender than those from females 12 to 17, 60 to 65, 72 to 77 and over 96 months of age. However, shear values of cores from 3 to 11-month-old females were not significantly different from those of females 78 to 95 months of age. Slaughter age significantly influenced sensory panel tenderness scores with roasts from 3 to 5-month-old females receiving significantly higher tenderness scores than all other age groups except the 6 to 11- and 30 to 35-month-old groups. The 12 to 17-month-old females tended to have both higher shear values and lower sensory panel tenderness scores than any of the other age groups below 41 months of age. Thus, the muscle from animals slaughtered between the ages of 12 and 17 months was less tender than at all other ages under approximately 41 months. A significant association was found between shear value and sensory panel tenderness score ($r = -.78$).

The simple correlation coefficients between marbling score and shear values ($r = -.01$) and sensory panel tenderness scores ($r = -.13$) were not significant. With chronological age held constant, the standard partial regression coefficients of marbling with shear values and panel tenderness scores indicated that marbling accounted for less than 2 per cent of the variation in muscle tenderness. Sensory panel scores for juiciness and flavor were positively associated with chronological age ($r = -.17$ and $r = 0.11$, respectively). However, on a marbling constant basis, the standard partial regression coefficients of age with panel juiciness and flavor scores indicated that chronological age accounted for less than 1 per cent of the variation in panel scores for juiciness and flavor. Marbling score was significantly associated with panel juiciness and flavor scores ($r = 0.48$ and $r = 0.36$, respectively), and the associations were not altered when considered on an age constant basis. Physiological age, as estimated by carcass maturity level, was equal to chronological age as an estimator of muscle tenderness and superior as an estimator of muscle juiciness and flavor.

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