THE INFLUENCE OF AGE ON VARIOUS FACTORS ASSOCIATED WITH BEEF QUALITY

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INTRODUCTION

Quality of beef is a topic with various implications to people involved in the different phases of production, merchandising and grading. The livestock producer may use the term to reflect his judgment of the condition of the beef animals with regard to fatness, conformation and general well-being. The merchandiser measures quality in terms of such carcass characteristics as fat covering, conformation, firmness, color and marbling. The meat grader considers, in addition, other factors such as texture of the lean and evidences of maturity. The emphasis placed on these characteristics will vary greatly among those associated with the livestock and meat industry.

In retail markets, the measure of quality is dominated by consumer reaction. Thus the visual characteristics, i.e., color and fat-to-lean ratio, are of prime importance. In production and merchandising, "quality of beef" implies its "saleability"; while to the consumer it means "eatability."

The importance of carcass maturity in beef has been recognized for many years; however, the number of experiments designed to study this factor has been limited. Maturity (physiological age) and marbling are considered the most important factors in establishing Federal grades for carcass beef. The general opinion, at the present, is that maturity has an adverse effect on beef quality. The Federal grade standards have taken this into account by stating that "within any specified grade, the degree of marbling required increases progressively with advancing maturity."

In recent years the emphasis placed on maturity in the Federal grading of beef has been questioned. Some evidence would indicate that maturity may be overemphasized. Clarification of the importance of maturity in relation to the other quality factors would benefit all phases of the industry, especially in marketing.

This study is part of a beef maturity project being conducted at the Oklahoma Agricultural Experiment Station. Maturity, as used in this study and by the Federal Grading Service, refers to the visual evidences of physiological age in the carcass or cut as distinguished from age. Animals whose ages varied from 6 to 90 months were used in an attempt to produce beef showing various stages of physiological maturity. This study was designed to evaluate: (1) the influence of age on the meat characteristics related to quality, (2) the influence of marbling on the various quality factors at various stages of chronological age, and (3) the influence of aging on muscle tissue from animals differing in marbling and chronological age.

REVIEW OF LITERATURE

This review considers some of the work relative to the following: (1) marbling and its influence on beef quality, (2) aging and its influence on beef quality, and (3) the influence of animal age on some of the chemical and physical properties of beef.

Studies on the palatability of meat were very few and limited in nature prior to 1924; however, in 1924 there began an effort on the part of animal husbandmen to analyze the quality and palatability of meat. In that year the U. S. Department of Agriculture initiated a cooperative study related to quality and palatability of meat. This work was well underway by 1926 (Mackintosh and Hall, 1936). Since that time an increasing amount of research has been accomplished on meat quality. A review of a portion of these findings is presented.

Marbling and Its Influence on Beef Quality

Fatness has long been used as a major consideration for evaluating slaughter livestock; in general, fatter beef is graded higher than that with less fat. However, in recent years some doubts have been expressed concerning the popularly-accepted belief that more fat, and particularly marbling, is associated with a definite superiority in beef palatability. Under the present system of grading a few flecks of fat present or absent in the muscle may easily change the grade and carcass value. This could make the difference between a profit or loss for either the packer or producer. Due to conflicting evidence in the literature the controversy may well be justified.

Mackintosh and Hall (1936) studied the relationship between tenderness and marbling in 63 beef cattle of different ages and degrees of finish. The relationship between tenderness, as measured by mechanical shear, and marbling, as measured by a grading score chart, was very high (r = 0.650). The same comparison, using palatability committee scores for tenderness, gave an even higher correlation (r = 0.675).

Hankins and Ellis (1939) studied the relationship between tenderness and fatness in 797 cattle and 924 lambs. Their correlations between indices of fatness and tenderness were low and inconsistent with regard to sign. They concluded that variations in tenderness were probably due to factors other than fatness.

Branaman et al. (1936) reported that the tenderness characteristics of meat were not definitely affected by increasing the degree of finish of steers and heifers. Their results indicated that the meat was quite tender at the beginning and remained so throughout the experiment.

Nelson et al. (1930) observed that beef from feeder calves was less tender than beef from similar cattle after fattening. However, Ramsbottom et al. (1945) stated that changes in muscle fibers and connective tissue may have occurred as fat content increased during the fattening period.

Batterman et al. (1952) took muscle samples by biopsy at the beginning of the feeding period and at slaughter on eight aged cows. The beginning live grade was cutter and the grade after feeding was utility. They noted a highly significant increase in fat and a general increase in total protein. Histological examination of the <u>semimembranosus</u> muscle showed that the connective tissue fibers had become more finely divided. Shear tests showed that they also had become more tender after fattening.

Black et al. (1940) conducted a feeding trial involving feeding supplements to steers maintained on grass. No differences were observed in palatability between roasted 9-10-11 rib cuts from the grass-fed groups and grass $\neq$ concentrate-fed groups. However, the difference in the ether extract of the edible portion ranged from 37.3 to 28.8 percent.

Simone (1955) working with 20-to 27- month-old cattle found a low correlation ($r = 0.232$ to 0.379) between tenderness of rib roasts and percentage of fat in the carcass.

Cover et al. (1956) noted that fatness was more closely correlated with tenderness scores in the bottom round than in the loin. Tenderness scores also were more closely related to ether extract values than to other measures of fatness. None of these correlation coefficients, however, were very high. When loin steaks were cooked by broiling, variations in fatness accounted for a maximum of 10 percent of the variation in tenderness and about 25 percent of the variation in juiciness. In braised bottom round steaks, the variation in fatness accounted for about 30 percent of the variation in tenderness and about 5 percent of the variation in juiciness.

Cover et al. (1958), in a study involving 203 beef carcasses of variable, but known history, reported the effect of carcass grades and fatness on tenderness. Marbling, when measured as percentage of ether extract of the rib-eye steaks, seemed to be significantly correlated with tenderness as measured by the mechanical shear resistance of the broiled steaks, but the highest correlation was $r = -0.330$. This accounted for less than 11 percent of the total variation, leaving about 89 percent of the reported variation in tenderness unaccounted for.

Palmer (1957), in a study using 32 steers, reported a correlation of -0.178 between shear force tenderness measurements and the ether extract of the rib-eye; this relationship accounted for 3.2 percent of the total variation in shear tenderness measurements.

Simone et al. (1958), in summarizing a three-year study involving 48 Herefords of different ages and grades, found a low relationship (r = 0.314) between tenderness and percentage of fat in the rib-eye. However, marbling was more closely related to tenderness than to total fat in the carcass. In this study it was also noted that the higher-graded carcasses were the more youthful carcasses.

Wellington and Stouffer (1959), using 121 beef cattle of widely differing fat content and marbling, measured the effect of marbling on two palatability factors: tenderness and juiciness. Differences observed in tenderness, as measured by mechanical shear resistance of cooked rib-eye steaks, were not significant, but an experienced palatability panel observed a significant increase in tenderness with the more abundant marbling. However, the tenderness differences associated with marbling detected by the panel accounted for only about 7 percent of the tenderness variability.

Alsmeyer et al. (1959), holding animal age constant, found that marbling influenced the tenderness of Brahman progeny more than Shorthorn progeny. When holding age constant, a highly significant partial correlation coefficient of 0.29 was found between marbling and panel tenderness for Brahman progeny. The corresponding coefficient for Shorthorn progeny was a significant 0.20. The same authors, using 502 animals ranging in age from 5 to 30 months, found that marbling accounted for only 8 percent of the panel tenderness variability. Marbling varied from devoid to modest.

Aging and Its Influence on Beef Quality

The term aging as used in this thesis is synonymous with tenderizing, conditioning, ripening or hanging.

Lehmann (1907), in his extensive study of the tenderness of muscles and its causes, was one of the first to report that aging increased the tenderness of beef.

The tenderness of beef is quite markedly affected during the first 24 hours after slaughter. Beef, prior to the onset of rigor mortis, is comparable in tenderness to meat removed from the carcass after resolution of rigor mortis. During rigor mortis, however, the muscle fibers are contracted and the meat becomes comparatively tough.

In general, there is agreement that the principal chemical changes which occur in muscle during the interval between death and the onset of rigor mortis involve a decrease in glycogen content, pH, adenosine triphosphate (ATP), and creatine phosphate; and increase in lactic acid, ammonia, and the breakdown products of ATP; and eventually the formation of actomyosin to give a rigid, inflexible, tough muscle. There is no general agreement among workers, however, on the chemical changes associated with the resolution of rigor mortis. This directly reflects the lack of knowledge concerning the tenderization of meat that takes place during aging.

Although the principal effect of aging on the organoleptic properties of beef is usually considered to be an increase in tenderness, the extent of this change does not always bear a direct relation to the length of storage. Hoagland et al. (1917) reported that beef stored for 2 to 4 weeks was almost as tender as that stored a much longer time.

Paul et al. (1948) removed and cooked paired steaks at the following time intervals after slaughter; 1-1½, 6, 13, 25, 49-54 and 145-150 hours. They noted that the force required to shear the cores increased for the first 13 hours, then decreased.

Ramsbottom and Strandine (1949), in a study using 10 heifer and cow carcasses, measured the initial and subsequent changes in tenderness over a 12-day period. They found the beef to be more tender 2 hours after slaughter than at any time thereafter for the next 2 to 6 days. Beef which was aged at 35° F. for 12 days was considerably more tender than it was 2 hours after slaughter. They also noted that beef chilled in the carcass was more tender than beef which was boned and then chilled to 35° F.

The time interval between death and the onset of rigor mortis is often found to vary widely among animals. Bate-Smith and Bendall (1949) showed that this time was determined by two considerations: (1) the pH of the muscle at the moment of death (which is determined by activity immediately preceding death), and (2) the glycogen reserve of the muscle.

Deatherage and Harsham (1947) observed that some steaks appeared less tender at certain stages of aging, whereas others progressively increased in tenderness throughout the aging period. In general, they found that tenderness increased until 17 days; at 24 days there was no improvement; and finally at 31 days there was some improvement beyond the 17-day tenderness measurement.

Paul (1943), working with storage times of 0, 1, 2, 4, 9, and 18 days, indicated that tenderness increased up to 9 days of storage, but the change between 9 and 18 days was variable, indicating that most of the increase in tenderness was complete in 9 days. She also stated that ripening occurred faster in wholesale cuts than in quarters and halves.

Harrison et al. (1949) reported that the greatest increase in tenderness of certain beef muscles occurred the first 10 days of aging. Tenderness of all the muscles studied gradually increased up to 30 days, but when individual muscles were considered separately, increase in tenderness with aging was not always linear. Variations in aroma and flavor scores with aging of the roasts were not so great as variation among animals. Aroma and flavor scores reached a maximum with 10 days aging and decreased after 30 days aging.

Husaini et al. (1950) also noted an increase in the tenderness of beef from the 3rd to the 15th day post-mortem, with a significant, but not high, correlation between initial and final tenderness.

Blackmon (1960) working with animals 6, 18, 42, and 90 months of age observed that the 14-day aging period had a much greater influence on the tenderness of the steaks from the younger animals, as measured by the Warner-Bratzler Shear, than it did on those from the older groups. The taste panel scores also followed the same trend.

The resolution of rigor mortis has also been followed histologically by Harrison et al. (1949); Ramsbottom and Strandine (1949); and Paul et al. (1944). In the pre-rigor state the muscle fibers were found to be straight or slightly wavy. During the onset of rigor mortis, hard lumps began to appear which were associated with areas of extreme stretch on either side of the contracted lumps. This gave a "washboard" appearance to the muscle fiber. During the resolution of rigor mortis, the waves began to disappear and the fibers straightened out. Finally, after 4 to 12 days of aging, a gradual and progressive breaking and rupturing of the fibers took place. It was postulated that this disintegration of the muscle fibers was due to the action of proteolytic enzymes and/or to mechanical stresses placed on the stretched fibers. Histologically, two types of disintegration associated with aging were found; one was the increased fragility of the fiber striations, and the other was the loss of fiber striations over a more extensive area.

Arnold et al. (1956) noted that calcium and sodium were released from the cells to meat juice on post-mortem aging, and that there was a gradual decrease in the amount of potassium ions in the extract and juice over the 30-day period. They theorized that in the days following rigor mortis there was an increase in charge on the protein molecules due to the uptake of potassium ions. The result was a greater degree of hydration accompanied by increased tenderness. They noted, as had many authors previously, that pH increased with aging.

Zender et al. (1958) followed the natural aseptic and anaerobic degradation of muscle tissue for 150 days at 25° C., and for 15 days at 38° C. They observed a slow rise in the level of amino acids and a parallel decrease of "glycine-soluble proteins." They found that glycine-NaOH buffer at pH 8.4 to 8.6 compared favorably with classical solvents for the extraction of muscle proteins. This solvent did not denature the extracted proteins and its low conductivity enabled them to use the solution immediately after extraction for electrophoretic analysis. The electrophoretic pattern of muscle proteins also appeared to be modified during storage, as if proteins were first split into high molecular weight sub-units and only later into amino acids.

Whitaker (1959) stated that changes in tenderness brought about by aging may be associated with either one or a combination of the following factors: (1) changes in the connective tissue, (2) dissolution of actomyosin, (3) increased hydration of the proteins, and (4) proteolysis.

The Physical and Chemical Properties of Beef as Influenced by Animal Age

Palatability

The influence of animal age has been generally accepted to result in more tender meat from young animals and more flavorful meat from old animals. Results of scientific investigations, however, are not in complete agreement.

Nelson et al. (1930) found that beef from 2-year-old and yearling steers was more desirable than beef from calves in either the feeder or finished stages. The calves required more pounds of shear force than the yearling or 2-year-old steers, although taste tenderness was not greatly influenced by age.

Mackintosh et al. (1936) noted that shear force and collagen nitrogen were higher in mature steers than in yearling steers; however, the palatability factor was only slightly lower.

Barbella et al. (1939) observed that meat from animals under 11 months of age was least desirable for flavor. Flavor increased sharply at 11 to 18 months and continued to increase from 19 to 30 months. After this there was little change. Of the four sources of variation in flavor intensity of lean, age accounted for 83 percent of the total, breeding 9, fatness 5, and sex 3 percent.

Hiner and Hankins (1950) working with animals which ranged in age from $2\frac{1}{2}$ to 66 months found that as age of the animals increased, tenderness decreased. The difference between veal and cows was highly significant; whereas that between veal and beef from 500-pound steer calves was not.

Jacobson and Fenton (1956a) noted differences in the quality factors of beef from Holstein heifers of 8, 12, 16, and 20 months of age. The 8- and 12-month groups were rated higher in all factors than the 16- and 20-month groups. They (1956b) also observed that with an increase in age from 2 to 12 months the fat content and shear values of the cooked meat increased. There also was a small but consistent decrease in moisture. With increased age, scores for aroma, flavor, juiciness and tenderness tended to decrease after 12 months.

Dunsing (1959), working with consumer household panels, found that eating preferences were significantly related to carcass age, but not to grade. Eating preferences were consistently in favor of the steaks from the younger carcass and were more pronounced for steaks from the sirloin than from the short loin cut. She also found that panel members having an over-all eating preference for the younger carcass steaks indicated a pronounced preference for the tenderness factor; those having an eating preference for the older carcass steaks indicated stronger preferences for the two factors, flavor and juiciness.

Alsmeyer et al. (1959), in a study involving 281 animals which were from 5 to 87 months of age, found that among all progeny, slaughter age, with marbling held constant, had a slightly stronger influence on panel tenderness than did marbling with age held constant. Also, with marbling held constant, the effect of slaughter age on panel tenderness was more pronounced among Shorthorn than among Brahman progeny with highly significant coefficients of -0.39 and -0.26 respectively. In another study involving 502 animals these same authors obtained a correlation coefficient of 0.15 between tenderness and age at slaughter. The animal age varied from 5 to 30 months and marbling level from devoid to modest.

Cole et al. (1960), working with 100 beef ribs equally divided among the USDA grades of prime, choice, good, standard, and commercial, noted that the palatability scores were highest for the prime ribs and decreased by grade to the commercial ribs. Prime ribs required the least amount of force and commercial ribs the most force to shear a standard-sized meat core.

Blackmon (1960) observed that in comparing the tenderness of loin steaks after a 48-hour chill from animals 6, 18, 42, and 90 months of age, the difference between age groups was not significant. However, the tenderness of broiled, loin steaks aged 14 days decreased significantly with increasing animal age. The panel scores for juiciness and flavor of the loin steaks showed these palatability factors to be influenced only slightly by animal age.

Color

The first visual impression gained when selecting a beef roast or steak, more often than not, will determine its acceptability as a main dish for the preparation of an appetizing meal. This visual impression of the uncooked cut of beef includes color, fatness and composition or proportion of fat and lean. The color of fresh beef is due largely to the concentration and chemical state of myoglobin, and perhaps to some extent to hemoglobin, which remains in the tissue in the residual blood.

Color is not necessarily a guide to the eating quality of beef, but it is a psychological factor which has real importance to many people. There is considerable variation in the color of beef and the causes for many of these variations are not known; however, it is generally recognized that older, more mature animals will have darker-colored meat than younger animals.

Bull et al. (1930), Helser et al. (1930), Hostetler et al. (1937), Longwell (1936), Mackintosh and Hall (1935) and Towbridge et al. (1937) reported that the color of the muscle darkens with increasing age of the animal.

Another theory, a number of years ago, was that grass feeding of cattle supposedly resulted in darker-colored beef. Mackintosh and Hall (1935), Longwell (1936) and Black et al. (1940) reported no difference in color due to grass feeding when compared to dry lot feeding.

Lawrie (1950) demonstrated a significant increase in myoglobin concentration with advancing animal age. However, no relationship was found between level of nutrition and myoglobin concentration.

Mackintosh and Hall (1935) obtained correlations of 0.610 between finish (external covering) and brilliance (value) and 0.685 between finish and chroma. They also found a significant correlation between marbling and color. They theorized that the influence of marbling on the color attributes of the muscle may be due to one or both of two phenomena: (1) the affect of the added white coloring matter in the surface, and/or (2) the effect of the fat on the permeability of the tissue to oxygen.

Hall et al. (1944) reported a positive relationship between dark-cutting beef and high muscle pH (this is considering the very extremes in muscle color).

Winkler (1939), working with muscle in the normal pH range, concluded that factors other than pH are equally or possibly more important in determining the color of fresh meat from a given animal. He did, however, influence the color by injecting lactic acid or ammonia solutions into the muscle tissue.

Hankins and Ellis (1939), with observations on 729 cattle and 924 lambs, stated that an increase in fatness contributed little to changes in the color of lean in the animals studied.

Wilcox et al. (1953) reported that feeding varying amounts of sucrose for different time intervals before slaughter (6 hours to 14 days) generally resulted in slight increases in carbohydrate content, improvement in color, and lower pH values of fresh muscle in both beef cattle and swine.

Jacobson and Fenton (1956a), working with cattle 8, 12, 16 and 20 months of age, found a highly significant increase in the hue (Hunter a/b ratio) of both raw and roasted beef from the semimembranosus muscle with increasing animal age. The longissimus dorsi and psoas major muscles did not increase in hue significantly with age of the animals. The color variations found could not be explained on the basis of differences in pH.

Doty (1956) reported a summary of the results obtained from a three-year study involving 153 graded beef carcasses. The lean color of the raw rib-eye was determined by comparison with Munsell color plates. Color was very significantly related to carcass grade and extent of aging. The color of prime grade rib-eye was lighter than that of good or commercial grade and aged rib-eye was lighter in color than unaged rib-eye.

Craig et al. (1959), using a Hunter Color and Color Difference Meter which had been standardized with a Gardner Laboratory red plate No. A-78, obtained reflectance readings on sixty carcasses. The animals were fed six rations composed of different amounts of grain and grass. The authors found that the differences in color of lean were due to different amounts of fat and moisture rather than to a difference in the quantity of pigments present. The brightest samples prior to storage were also the brightest after storage.

Simone et al. (1959) noted that the meat from 30-month-old steers was darker (lower y value) than meat from the 18-month-old steers.

Meat Hydration

Meat hydration has been defined by Hamm (1959) as the interaction between meat proteins and water. This interaction influences the water-holding capacity which may be described as the ability of meat to hold fast its own or added water during application of any force (pressing, heating, chewing or grinding). The terms "free" and "bound" water have also been used by a number of researchers in describing the water-holding capacity of meat. A certain sharp limit, however, does not exist between these two terms. The amount of "free" or "bound" water one finds depends on the experimental method used. In most cases the values are only relative.

It is a well-known fact that the water-holding capacity of meat is very important in the processing of the various sausage products. Also it has been theorized by a number of researchers that color, juiciness, tenderness and flavor may be related to the water-holding capacity of meat.

Previously, the press had been used to determine the amount of expressible juice in meat, and its relationship to panel tenderness or juiciness. Child and Baldelli (1934), Satorius and Child (1938), Tannor et al. (1943), Hall et al. (1944) and Gaddis et al. (1950) used the amount of juice expressed from a meat sample (50-100 grams) as an indicator of juiciness or one of the other palatability factors. Generally, the relationships were quite poor. Gaddis et al. (1950) noted that possibly the palatability factors of juiciness are influenced not so much by amount of juice as by composition. They observed that fat added flavor, which stimulated saliva and increased the impression of juiciness during the chewing process.

The filter paper technique for determining the water-holding capacity of meat originated from the work of Grau and Hamm (1953). Wierbicki and Deatherage (1958) reported a modification of the Grau and Hamm technique of 1953. Both, however, were an attempt to measure the same characteristic of meat. This technique could be of practical use to the processor for determining the water-holding capacity of certain meat tissues before adding them to a sausage formula. On the other hand, the percent "free" or "bound" water may prove to be an indication of tenderness.

Hamm (1959), in a review on meat hydration, discussed some of the various factors that may possibly influence the protein-water interaction previously mentioned. He pointed out that water is a dipole; i. e., the negative charge of oxygen and the positive charge of hydrogen do not coincide and, therefore, water is a molecular magnet. This magnet is attracted by all kinds of polar groups in the protein. However, not all charged groups may bind water. Groups which compensate their charges by an inter- or intramolecular salt cross-linkage are not available for water molecules. Therefore only the net charge of protein has an influence on the water-holding capacity. Changes in meat hydration are not only affected by a change in the net charge of proteins, but also by "steric factors." In the molecular network of a native protein a number of charged groups are not available for water binding since there is insufficient space for the water molecules. Cleavage of the cross linkages permits the peptide chains to become more flexible so that water can attach to the polar groups.

Hamm also observed that the normal pH of meat, about 5.5, is close to its isoelectric point and therefore the water-holding capacity is fairly low. Any increase in pH will increase the degree of hydration.

Certain bivalent metallic cations are also listed by Hamm as important in meat hydration, in spite of their low concentration. Hamm and other German workers have found that magnesium (25 mg. percent) and calcium (5 mg. percent) and perhaps even zinc (3 mg. percent) decrease the water-holding capacity of muscle. By removing metallic cross linkages more charged groups become available for water binding.

The modification by Wierbicki and Deatherage (1958) gave a formula for determining the amount of "free water" as a percentage of the total. They stated that "the amount of free water in beef, pork, veal, and lamb varied from 30 to 50 percent of the total moisture content, depending on the kind of meat and period of aging." The percentage of "bound water" equals 100 minus the percentage of "free water."

Hamm (1959) stated that there was a correlation between the area of pressed meat and its degree of hydration.

Briskey et al. (1959) used the filter paper technique to determine the ratio of the muscle area to the water area in an attempt to determine more about the chemical and physical characteristics of pork muscles.

No significant differences were noted among four classes of hams which varied from pale, soft and watery, to dark and dry.

In comparing the physical and chemical properties of eight pork muscles, Briskey et al. (1960) again used the filter paper technique, modified somewhat from that used in 1959. This time they measured the expressible water and reported it as a percentage of the total water using a modification of the formula reported by Wierbicki and Deatherage (1958).

Simone et al. (1961), using the technique of Wierbicki and Deatherage, obtained correlations of 0.64 and 0.86 between percent "bound water" and tenderness and juiciness.

Chemical Composition

The chemical composition of mammals has been considered for many years to be practically constant when expressed on a fat-free basis, with the exception of percent moisture. Evidence of this has been shown by various investigators.

Murry (1922) has divided the composition of animal bodies into two main divisions, namely, fat and non-fatty matter. The non-fatty matter consists primarily of water, protein, and ash. He found that the percentage of water varied with the age of the animal in a definite manner. Murry also related that the ratio of protein to ash did not change with the age of the animal, but may be influenced to a certain extent by the ration fed an animal.

Similar results have been reported by Moulton (1923), who stated that chemical maturity in cattle is reached at about five months after birth. After this time, the chemical composition of the animal on the fat-free basis is practically constant. Moulton's data showed a slight decrease in water, and a slight increase in percent ash and protein, with advancing age.

Blackmon (1960) stated that the chemical composition of the *longissimus dorsi* muscle was not significantly influenced by animal age, with the exception of percent moisture. The generally-recognized trend for percent moisture to decrease with age was observed.

EXPERIMENTAL PROCEDURES

Materials

Fifty-six Hereford steers and females from the Oklahoma Agricultural Experiment Station herd were used for this study. Animals were selected to fit the 6-, 18-, 42-, or 90-month age groups. "Slight amount" and "slightly abundant" marbling levels were preferred for each age group. An outline of the original experimental design of the project is shown in Table I. The animals were fed in an attempt to reach one of the desired marbling levels and still be within 10 percent of the desired age. All animals were of similar genetic and management background. The 18-, 42- and 90-month-old animals received a ration consisting of ground ear corn, chopped alfalfa hay, cottonseed hulls, cottonseed meal, bran, whole oats, and molasses fed ad libitum. The 6-month-old calves were creep-fed while on nurse cows for the complete term prior to slaughter. No 6-month-old calves with a slightly abundant amount of marbling were obtained so the statistical analysis, which is described later, did not follow the original plan. General carcass data on each of the animals are listed in Appendix Tables XXXIII and XXXIV.

Methods

Slaughtering and cutting were done at the Oklahoma State University Meat Laboratory and at a small packing plant in Oklahoma City in accordance with the methods described in the Proceedings of the Fourth (Deans,

TABLE I

THE ORIGINAL EXPERIMENTAL DESIGN OF THE PROJECT FROM WHICH DATA FOR THIS STUDY WERE OBTAINED

AGE	6 Mo.		18 Mo.		42 Mo.		90 Mo.	
MBLG LEVEL	SL. AMT.	SL. ABT.	SL. AMT.	SL. ABT.	SL. AMT.	SL. ABT.	SL. AMT.	SL. ABT.
MUSCLE	L S	L S	L S	L S	L S	L S	L S	L S
AGING PERIOD	2 14 2 14	2 14 2 14	2 14 2 14	2 14 2 14	2 14 2 14	2 14 2 14	2 14 2 14	2 14 2 14
ANIMAL NO.								
1	Choice*	Prime+	Good	Prime	Standard	Choice	Utility	Commercial
2	"	"	"	"	"	"	"	"
3	"	"	"	"	"	"	"	"
4	"	"	"	"	"	"	"	"
5	"	"	"	"	"	"	"	"
6	"	"	"	"	"	"	"	"

L -------- <u>longissimus dorsi</u>
S -------- <u>semitendinosus</u>
2 -------- 2 days post-mortem
14 ------- 14 days post-mortem
* -------- The desired carcass grade for each cell
SL. AMT. -- Slight amount marbling level
SL. ABT. -- Slightly abundant marbling level

1951) and Sixth (Wellington, 1953) Reciprocal Meat Conferences. Feed was withheld 24 hours prior to slaughter, but the animals were allowed free access to fresh water. The slaughtering was done during the years 1959 and 1960.

Immediately after slaughter and dressing, the carcasses were placed in a 34-36° F. cooler for a 2-day chilling period. The carcasses were then weighed and ribbed prior to evaluation of the various maturity, conformation, and quality factors and determination of a Federal grade. The score card used by the Federal grader and codes for the statistical analysis are shown in Figure 1. Each characteristic listed was evaluated by the same grader for each carcass. These characteristics, as well as the Federal carcass grade, were coded for statistical analysis.

Both the right and left sides of the carcasses were then divided into wholesale cuts. The longissimus dorsi muscles from the wholesale loin from both sides of each carcass were studied. The left sides of all carcasses were sampled at 2 days post-mortem (aging). The loins from the right sides were held 14 days post-mortem (aging) at 34-36° F., then the muscles were sampled. The sampling locations for the longissimus dorsi muscle are shown in Plate I,1. The bone and excess fat (trimmed to 3/8 inch) were removed from each steak. Each steak was wrapped individually, quick-frozen in an air blast freezer (-10° F.) and then held at -20° F. until the time of evaluation.

Cookery, Shear and Organoleptic Evaluation

Shear force values were determined by the Warner-Bratzler shearing device. The values presented are the number of pounds of mechanical force required to shear a core of cooked meat 1 inch in diameter. The 2-inch steaks used for shear tenderness evaluation were removed from the

CARCASS BEEF VISUAL OBSERVATIONS

Carcass No.____ Date________ Grader_______
Class (Sex)____ Weight______ Grader_______
Age_________

REDNESS OF RIB	
Very Red	6
Red	5
Mod. Red	4
Sl. Red	3
Tra. Red	2
Dev. Red	1

CARTILAGE OSSIFICATION	
Soft and Pearly White	6
Slightly Ossified	5
Mod. Ossified	4
Nrly. Comp. Ossified	3
Completely Ossified	2
Hard and Flinty	1

COMPACTNESS	
Very Plocky	8
Blocky	7
Mod. Blocky	6
Sl. Blocky	5
Sl. Rangy	4
Rangy	3
Very Rangy	2
Ext. Rangy	1

FLESHING	
Very Thick	8
Thick	7
Mod. Thick	6
Sl. Thick	5
Sl. Thin	4
Thin	3
Very Thin	2
Ext. Thin	1

PLUMPNESS OF ROUND	
Very Plump	8
Plump	7
Mod. Plump	6
Sl. Plump	5
Flat	4
Sl. Concave	3
Concave	2
Very Concave	1

SYMMETRY	
Very Symmetrical	8
Symmetrical	7
Mod. Symmetrical	6
Sl. Symmetrical	5
Sl. Unsymmetrical	4
Mod. Unsymmetrical	3
Unsymmetrical	2
Very Unsymmetrical	1

DIST OF FAT (EXTERNAL)	
Very Uniform	7
Uniform	6
Mod. Uniform	5
Sl. Uneven	4
Mod. Uneven	3
Uneven	2
Very Uneven	1

FIRMNESS OF FAT	
Very Firm	7
Firm	6
Mod. Firm	5
Sl. Soft	4
Soft	3
Sl. Oily	2
Oily	1

INTERNAL FATS	
Very Abundant	8
Abundant	7
Mod. Abundant	6
Sl. Abundant	5
Mod. Amount	4
Small Amount	3
Traces	2
Devoid	1

MARBLING			
Ext. Abund.	12	Sm. Amt.	5
Very Abund.	11	Sl. Amt.	4
Abundant	10	Traces	3
Mod. Abund.	9	Prac. Dev.	2
Sl. Abund.	8	None	1
Moderate	7		
Modest	6		

TEXTURE	
Very Fine	7
Fine	6
Mod. Fine	5
Sl. Coarse	4
Coarse	3
Very Coarse	2
Ext. Coarse	1

FIRMNESS (LEAN)	
Very Firm	7
Firm	6
Mod. Firm	5
Sl. Soft	4
Soft	3
Very Soft	2
Ext. Soft	1

COLOR OF FLESH	
Dark Pink	7
Very Lt. Cherry Red	6
Lt. Cherry Red	5
Cherry Red	4
Mod. Dark Red	3
Dark Red	2
Very Dark Red	1

Figure 1. The Federal Graders' Score Card with the Codes for Statistical Analysis

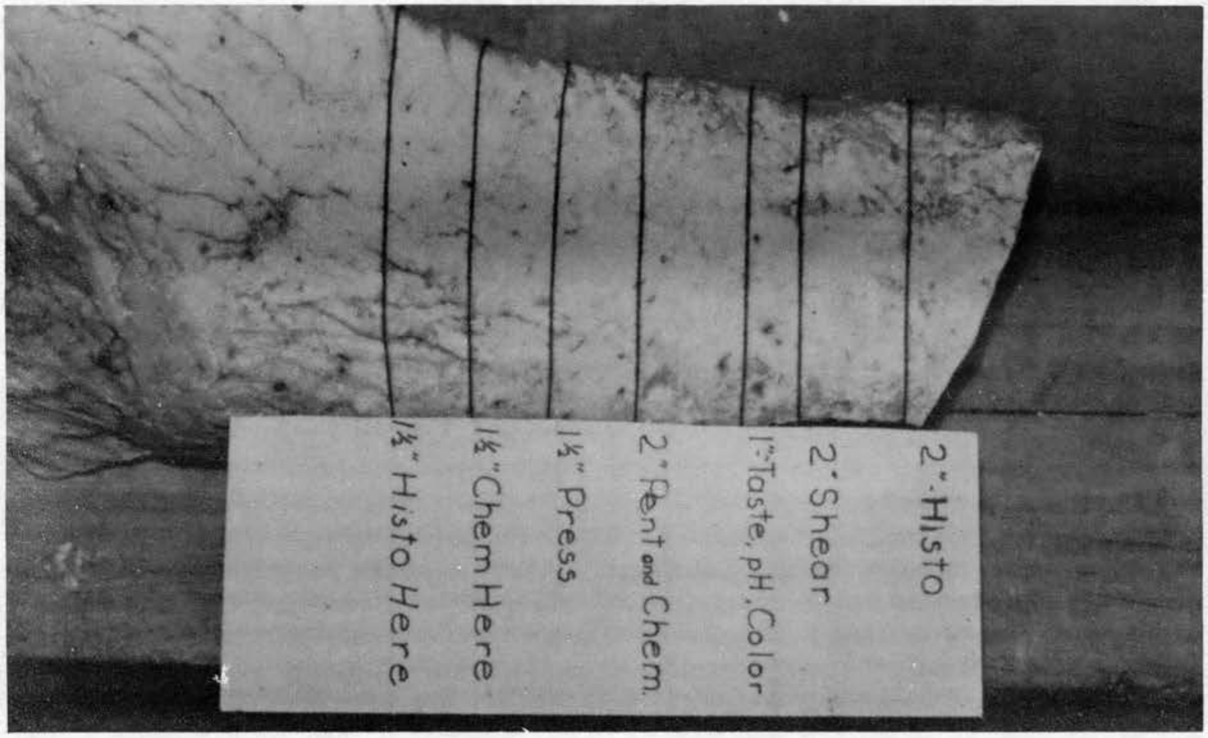
-20° F. freezer and thawed in a 40° F. cooler for 12 to 14 hours. An open-face, gas, griddle-broiler was used to broil the steaks. The broiler was preheated for 30 minutes to an internal temperature of 350° F. prior to inserting the steaks. Each steak was placed in the broiler so that the top surface was approximately 4 inches from the overhead flame. An internal temperature of 150° F. was used to determine the degree of doneness, the steaks being turned so that both sides were done equally. Internal temperature was determined by the use of thermocouple leads from a multi-point recorder, or with meat thermometers. Precaution was taken to locate the tips of the thermocouples or thermometers in the center of each of the steaks.

Three cores (lateral, dorsal and medial), 1 inch in diameter, were removed from the longissimus dorsi muscle for shear measurements, as shown in Plate I,2. Three shears were made on each core, giving a total of 9 shear values per steak. The average of these 9 values was used for statistical analysis. All shears were determined as soon as possible after the steaks were removed from the broiler.

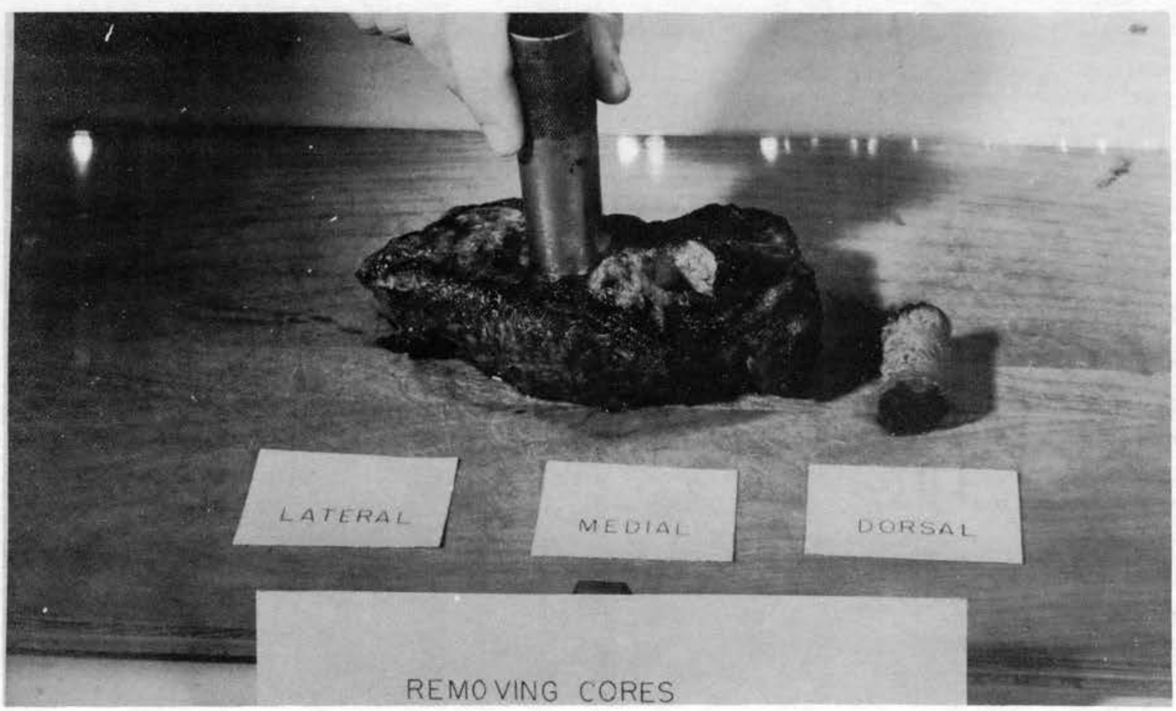
Steaks used for organoleptic evaluation were 1-inch-thick and handled in the same manner as the steaks for shear determination. Cores, three-fourths inch in diameter, were removed from the longissimus dorsi muscle of the steaks for taste analysis. These cores were small enough to allow 6 to 10 samples to be obtained from each steak, and at the same time each was a desirable "bite size" portion.

A maximum of 6 samples were evaluated at any one sitting, and usually only one sitting was accomplished per day. Never more than two sittings were required of the panel per day. The days on which two sittings were required, one was held between 10 and 12 a.m. and the other between 3 and

PLATE I



1. Sampling Locations for the Longissimus Dorsi Steaks



2. Location of the Three One-Inch Shear Cores in the Longissimus Dorsi Muscle

4 p.m. The time of day at which single sittings were held was also at one or the other of these periods.

The panel used throughout this study consisted of experienced staff members and research assistants. The number of members present at each of the sittings ranged from 6 to 10. Panel members were instructed to score each of the samples for tenderness, juiciness, and flavor, using the score sheet presented in Figure 2. Bread and a rinse of tap water were provided for use by the judges between samples. The organoleptic values to which statistical analysis was applied were average panel scores for tenderness, juiciness, and flavor.

An 8-point hedonic scale without a neutral point was used for scoring the samples, with a score of 8 being the highest rating and 1 the lowest. This same scale was used for all of the taste panel factors evaluated.

Cooking Loss

Cooking loss was determined on the same steaks that were used for shear determinations. The weight of each thawed steak was recorded to the nearest 0.5 gram just prior to placing it in the broiler. Immediately upon removal of the steak from the broiler the weight was again taken. The weight loss during the cooking period was expressed as a percentage of the original or precooked weight.

Chemical Determinations

pH--The majority of the pH readings were taken with a Beckman Zeromatic instrument using a combination electrode (glass and reference electrodes in one unit). Due to mechanical failure of this instrument, a few readings were taken with a Beckman portable and also a Leeds-Northrup

SCORE CARD FOR QUALITY FACTORS

	TENDERNESS		FLAVOR		JUICINESS
8. Extremely Tender		Extremely Desirable		Extremely Juicy	
7. Very Tender		Very Desirable		Very Juicy	
6. Moderately Tender		Moderately Desirable		Moderately Juicy	
5. Slightly Tender		Slightly Desirable		Slightly Juicy	
4. Slightly Tough		Slightly Undesirable		Slightly Dry	
3. Moderately Tough		Moderately Undesirable		Moderately Dry	
2. Very Tough		Very Undesirable		Very Dry	
1. Extremely Tough		Extremely Undesirable		Extremely Dry	

Figure 2. Taste Panel Score Sheet

unit. The average of three readings taken directly on each steak was used for the statistical analysis.

Proximate Analysis--The muscle samples for proximate analysis were taken from the -20° F. freezer and the outer edges containing fat and connective tissue removed. The frozen muscle portion remaining was cut into small cubes with a band saw, placed in a sample bottle and returned to the freezer. As the samples were needed for analysis, they were removed from the freezer and the small meat cubes, in a partially frozen state, were blended to a pasty consistency. This blended mass was then returned to the sample bottle and transferred to the University's Biochemistry Department laboratories for analysis. Here again the samples were frozen until the time of analysis. Association of Official Agricultural Chemists procedures, as outlined in the sixth edition (1945), were followed in conducting the analyses.

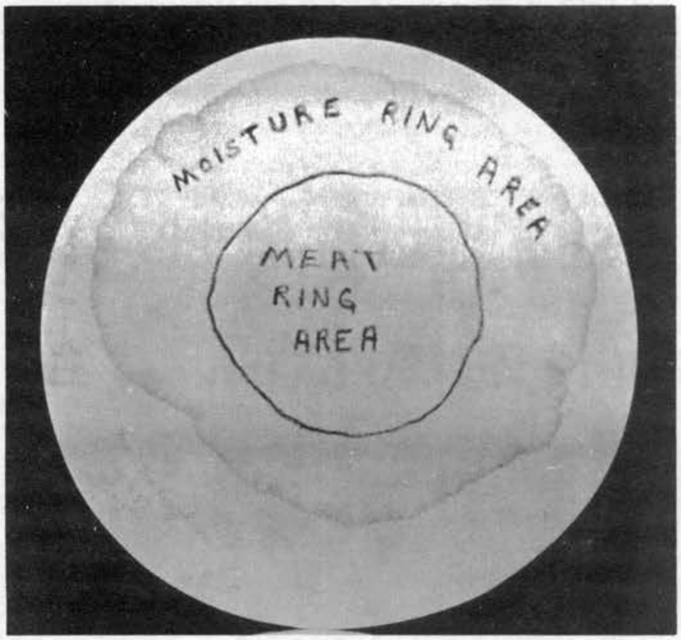
Expressible Fluids

Expressible fluids were determined by using a Carver Press and a modified version of the Wierbicki and Deatherage filter paper technique (1958). The steaks to be sampled for this determination were removed from the -20° F. freezer the afternoon prior to pressing. Three 500 mg. samples were removed from the center of the steak. Each 500 mg. aliquot was then placed on a filter paper which was on a 6 x 6 inch Plexiglas plate. The three samples were tiered between 4 Plexiglas plates and pressed simultaneously. Whatman No. 1 filter papers were scattered in a desiccator over saturated KCl, 15 hours prior to using, to standardize the moisture content of all papers. The loaded press then was pumped up to 18,000 pounds pressure on the plate or 500 pounds per square inch and held there for one minute, then the pressure was released. The outline of the meat ring was traced before the filter paper was removed from the Plexiglas plate. The moisture ring did not migrate during the drying period so was not outlined in pencil. Each filter paper was carefully removed from the plate to avoid tearing. The moisture ring and meat ring areas were then measured using a compensating polar planimeter. The moisture ring ≠ meat ring area was determined by measuring the outer moisture ring. The meat ring area was determined by measuring the meat ring outline. The difference between the outer moisture ring and meat ring area represents the moisture ring as demonstrated in Plate II,1. The moisture ring-to-meat ring ratio was determined by dividing the meat ring area into moisture ring area.

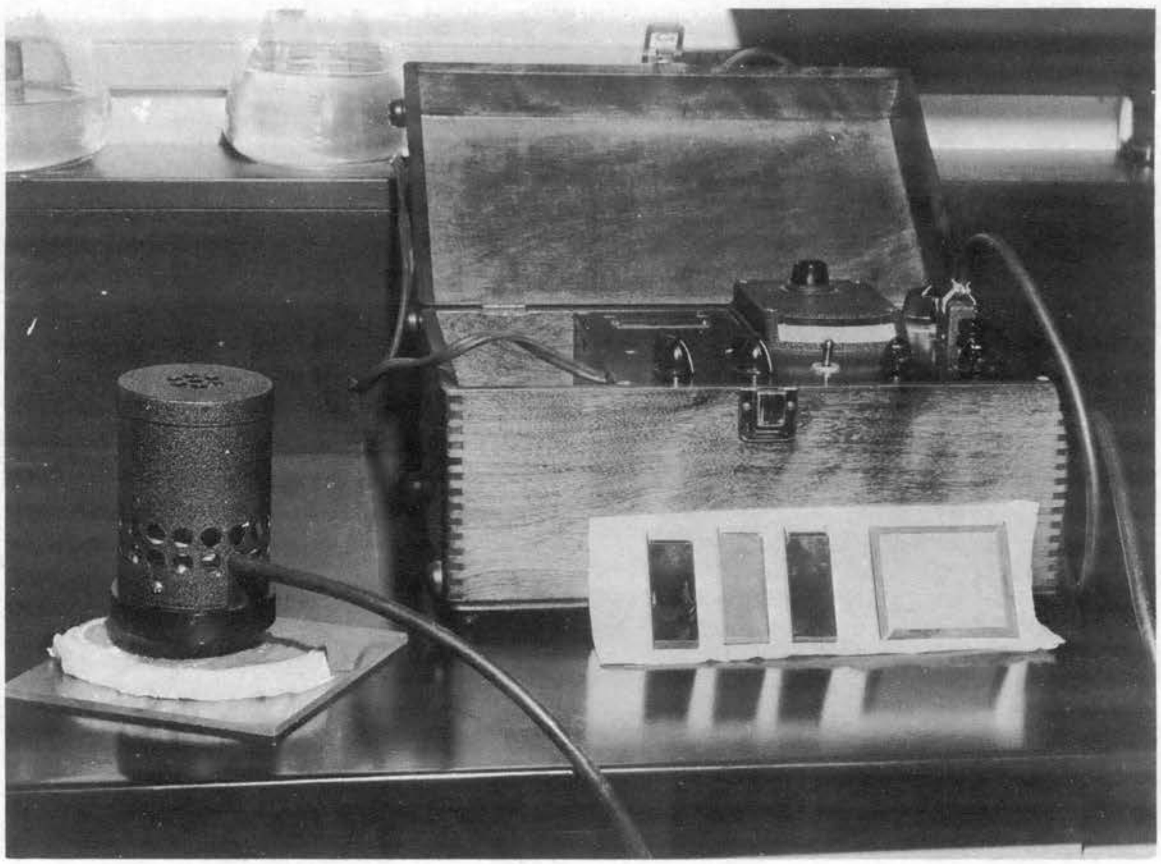
Color

Tristimulus Munsell color notations were obtained by using a Photovolt Reflectance Meter. The readings were taken on fresh steaks approximately 1 hour after cutting (Plate II,2). The reflectance meter was standardized, prior to each series of readings, using a 5R/4/14 Munsell Color Chit. The reference points for the amber, green, and blue filters were 79.5, 39.0, and 15.0, respectively. The photoelectric cell was returned to the Munsell Standard Chit after each four readings to see that the galvanometer was on the reference point. The values obtained from these three readings on each steak were then inserted into the formula outlined in the U.S. Department of Commerce Circular C429 (Hunter, 1942) and the x and y values calculated. These were plotted on the Munsell Value Charts to determine the correct hue and chroma notations. When the value notations were greater than ±0.1 from a whole number, the

PLATE II



1. Meat Ring and Moisture Ring Areas on the Filter Paper



2. Photovolt Reflectance Meter

hue notation and chroma notation were plotted on the two Munsell Charts that bracketed the value notation and the exact hue notation and chroma notation determined by interpolation. The three dimensions of color hue, value and chroma were analyzed as separate components.

Statistical Analysis

All data collected in this study were placed on cards for analysis with the IBM 650 Electronic Computer.

The analysis of variance was utilized to study the effect of animal age, marbling and aging on the various chemical and physical traits of beef. Animals 18, 42, and 90 months of age were used in the experimental design shown in Table II. This will be termed Analysis I.

The experimental design shown in Table III was used to compare the 6-month calves with all other age groups. The analysis of variance method was also utilized in analyzing these data. This will be termed Analysis II. The analysis of variance tables for both designs are shown in the Results and Discussion Section.

All 56 animals were included in the simple correlation coefficients reported. Sorting was done only with regard to animal age to determine the correlation coefficients within each age group as a comparison to the over-all (pooled age groups) correlation coefficients.

The abbreviations sl. amt. and sl. abt. when used in this study refer to slight amount and slightly abundant levels of marbling.

TABLE II

THE EXPERIMENTAL DESIGN FOR ANALYSIS I

	Slight Amount Marbling Level		Slightly Abundant Marbling Level	
Age (Months)	2 Day[1] Sample	14 Day[2] Sample	2 Day Sample	14 Day Sample
18	60[3] 942 941 5760		3933 4560 3660 909	
42	733 296 236 515		157 719 267 527	
90	662 592 802 262		903 683 753 503	

TABLE III

THE EXPERIMENTAL DESIGN FOR ANALYSIS II

	Age (Months)			
Aging Period in Days	6	18	42	90
2[1]	215[3] 944 945 059 093	60 942 941 5760 933	733 296 236 515 295	662 592 802 262 612
14[2]				

[1]Left *longissimus dorsi*
[2]Right *longissimus dorsi*
[3]Animal numbers used to fill each pair of cells, carcass information on each animal is located in Tables XXXIII and XXXIV of the Appendix.

RESULTS AND DISCUSSION

The results of Analyses I and II are presented and discussed as part 1 and part 2 for each group of factors studied.

Palatability

Part 1

The tenderness of *longissimus dorsi* steaks, as evaluated by the Warner-Bratzler shear and the taste panel, decreased with increasing animal age (Table IV). Both criteria revealed a greater decrease in tenderness between the 18- and 42-month age groups than between the 42- and 90-month age groups. From this it appeared that animal age may be more critical, with regard to tenderness, at a point between 18 and 42 months than at any other age. In considering the work of Dunsing (1959) and Simone (1959), this critical age for tenderness may fall in the range of 18 to 30 months. Unpublished work by Henrickson (1960) would indicate that the *longissimus dorsi* muscle may reach maximum tenderness at 12 to 14 months of age.

The marbling levels used in this study were not significantly associated with the tenderness of *longissimus dorsi* steaks as evaluated by the taste panel (Table V). However, the panel scores indicated that steaks from carcasses displaying "slightly abundant" marbling were a bit more tender than those from carcasses with a "slight amount" of marbling (Table IV).

Shear force values, however, were significantly lower for steaks

TABLE IV

PALATABILITY, SHEAR FORCE, AND COOKING LOSS MEANS FOR LONGISSIMUS DORSI STEAKS FROM CATTLE OF THREE AGE GROUPS, TWO MARBLING LEVELS, AND TWO AGING PERIODS

Age (Months)	Panel[1] Tenderness	Shear[2] Value	Panel[1] Flavor	Panel[1] Juiciness	Cooking[3] Loss
18	6.50	10.56	6.30	5.22	28.39
42	4.80	18.18	5.98	5.32	32.26
90	4.88	19.07	6.22	5.66	33.26
Aging Days					
2	5.20	16.23	6.14	5.48	31.43
14	5.59	15.65	6.19	5.33	31.17
Marbling Level					
Sl. Amt.	5.28	17.65	6.08	5.49	29.54
Sl. Abt.	5.52	14.23	6.25	5.31	33.06

[1]A score of 8 equals extremely tender, desirable flavor or juicy; 1 equals extremely tough, undesirable flavor, or dry.
[2]Expressed in pounds, the greater the number of pounds the less tender the steak.
[3]Expressed as a percent of the precooked weight.

TABLE V

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE PALATIBILITY FACTORS SHEAR VALUE, AND COOKING LOSS OF LONGISSIMUS DORSI STEAKS FROM CATTLE OF THREE AGE GROUPS, TWO MARBLING LEVELS, AND TWO AGING PERIODS

Source	d.f.	Panel Tenderness M.S.	Shear Value M.S.	Panel Flavor M.S.	Panel Juiciness M.S.	Cooking Loss M.S.
Total	47					
Age	2	146.00***	3503.75***	4.60	8.65	1058.90*
Marbling	1	6.80	1404.30***	3.50	3.70	1487.60*
Age x Marbling	2	5.35	566.50*	.70	10.20	133.35
Animals[1]	18	9.34	135.13	1.99	6.48	203.92
Aging	1	18.00*	40.30	.30	2.70	7.80
Aging x Marbling	1	9.90	120.90	.10	3.70	1035.40*
Aging x Age	2	7.95	63.20	.00	1.00	18.35
Aging x Age x Marbling	2	7.90	8.95	.15	.55	168.05
Aging x Animals[2]	18	3.07	37.57	1.26	4.26	169.86

* $p < 0.05$
*** $p < 0.005$

[1]Mean square used to test age and marbling.
[2]Mean square used to test aging.

from the "slightly abundant" marbled cattle than steaks from the "slight amount" group (Table IV). The difference in results observed between these two measures of tenderness is not readily explained; however, the qualities evaluated by each method are somewhat different. The shear measures the force required to cut a core of meat and does not consider other factors associated with taste-tenderness sensations, such as, softness to tongue and cheek, softness to tooth pressure, ease of fragmentation of muscle fibers, mealiness of muscle fibers, and tenderness of connective tissue, as discussed by Cover and Hostetler (1960).

The significant age x marbling interaction for shear force also indicated that all age groups were not related to marbling in the same manner (Table V). Marbling did not appear to be related to tenderness in the 18-month age group (Table VI). However, increased amounts of marbling in the 42- and 90-month-old cattle increased the tenderness of the steaks.

TABLE VI

SHEAR VALUES IN POUNDS FOR LONGISSIMUS DORSI STEAKS SHOWING THE INTERACTION BETWEEN ANIMAL AGE AND MARBLING LEVEL

	Age (Months)		
Marbling Level	18	42	90
Sl. Amt.	10.15	20.53	22.26
Sl. Abt.	10.96	15.84	15.88

Steaks aged 14 days were significantly more tender, as scored by the taste panel, than those sampled at 2 days after slaughter (Tables IV and V). This is in agreement with the generally-accepted theory that "meat becomes more tender upon aging." This aging relationship was not observed when using the shear as a measure of tenderness, although the mean was slightly less for steaks aged 14 days compared to those aged 2 days (Table IV). Aging, however, did not give the same results for all age and marbling groups.

Taste panel scores suggested that steaks from the 42- and 90-month cattle of "slight amount" marbling were more tender after aging for 14 days (Table VII). This same trend was not observed for the 18-month-old cattle. They were very acceptable at both aging periods and a very high taste-tenderness score at 2 days would be difficult to increase at 14 days. An increase in panel tenderness was practically void for the "slightly abundant" marbling level of all age groups aged 14 days (Table VII).

TABLE VII

PANEL TENDERNESS SCORES AND SHEAR VALUES FOR LONGISSIMUS DORSI STEAKS FROM ANIMALS OF TWO MARBLING LEVELS, TWO AGING PERIODS, AND THREE AGE GROUPS

Age (Months)	Sl. Amt. Aging Days 2	Sl. Amt. Aging Days 14	Sl. Abt. Aging Days 2	Sl. Abt. Aging Days 14
	Panel Tenderness[1]			
18	6.70	6.35	6.43	6.53
42	4.18	5.33	4.82	4.90
90	3.95	5.18	5.15	5.28
	Shear Values[2]			
18	9.53	10.78	11.65	10.28
42	21.30	19.75	17.08	14.60
90	21.48	23.05	16.33	15.43

[1]Scoring system--8 extremely tender, 1 extremely tough.

[2]Expressed in pounds, the greater the number of pounds the less tender the steak.

Panel juiciness and flavor were not significantly associated with animal age, marbling level or aging. This is not in complete agreement with the generally-accepted theory that older animals produce meat with more flavor.

A greater cooking loss was observed with increasing animal age and higher marbling level (Table IV). Steaks from the older animals contained more fat (even after the 3/8 inch fat trim), had a larger outside surface area, and required longer to cook, thus a greater cooking loss would be expected.

The significant aging x marbling interaction (Table V) may be explained by observing the percentage of cooking loss given in Table VIII. Steaks from cattle in the "slight amount" marbling level and aged 14 days increased in cooking loss while those from the "slightly abundant" level, aged 14 days decreased in cooking loss.

TABLE VIII

THE PERCENTAGE OF COOKING LOSS FOR *LONGISSIMUS DORSI* STEAKS OF TWO MARBLING LEVELS AND TWO AGING PERIODS

Aging Days	Sl. Amt.	Sl. Abt.
2	28.20	34.66
14	30.88	31.47

Part 2

The panel tenderness results for this analysis indicated that steaks were less tender with increasing animal age (Table IX). The shear force means suggest the same trend, except for the 6-month age group, which had higher shear values than those reported for the 18-month age group. The average shear force required to cut the 1-inch core of meat was low

TABLE IX

PALATABILITY, SHEAR VALUE AND COOKING LOSS MEANS FOR THE LONGISSIMUS DORSI MUSCLE OF FOUR AGE GROUPS AND TWO AGING PERIODS

Age (Months)	Panel Tenderness[1]	Shear Value[2]	Panel Flavor[1]	Panel Juiciness[1]	Cooking Loss[3]
6	6.13	14.09	6.13	5.27	27.84
18	6.02	12.10	6.19	5.00	28.45
42	4.85	21.05	5.97	5.62	30.71
90	4.47	23.05	6.03	5.81	30.78
Aging Days					
2	4.91	18.84	6.07	5.52	28.75
14	5.83	16.31	6.09	5.34	30.15

[1]A score of 8 equals extremely tender, desirable flavor or juicy; 1 equals extremely tough undesirable flavor, or dry.
[2]Expressed in pounds, the greater the number of pounds the less tender the steak.
[3]Expressed as a percent of the precooked weight.

and very acceptable for both the 6- and 18-month age groups. The greatest difference among age groups, for both measures of tenderness, was again between the 18- and 42-month ages (Table IX). Shear values and panel tenderness scores for both the 42- and 90-month age groups were approaching the slightly tough level.

Aging 14 days significantly increased the tenderness of steaks as shown by both the Warner-Bratzler shear and panel tenderness (Table IX). These data also indicated that the increase in tenderness was more pronounced for some ages than for others (Table X). The tenderness of steaks from 6-month calves increased during the 14-day aging for both measures. The 18-month group showed essentially no change in tenderness, with both estimators in very close agreement (Table X). Panel tenderness indicated that steaks from the 42- and 90-month age groups increased considerably in tenderness during the 14-day aging. This trend was not present using shear force values as an estimate of tenderness, in fact, the 90-month shear values increased slightly during the 14-day aging period. Possibly, as noted in a report by Harrison (1949), muscles from old animals age more slowly than those of younger animals.

Flavor and cooking loss were not significantly associated with animal age or aging (Table XI). Six-month calves normally are thought to lack the flavor of older animals, however, the method of feeding and good condition at slaughter may have caused the more desirable flavor in the calves.

Panel juiciness scores indicated that the 42- and 90-month age groups were more juicy than the two younger age groups (Table IX).

TABLE X

PANEL TENDERNESS SCORES AND SHEAR VALUES FOR LONGISSIMUS DORSI STEAKS FROM ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

	Panel Tenderness[1]		Shear Value[2]	
	Aging		Aging	
Age (Months)	2 Days	14 Days	2 Days	14 Days
6	5.48	6.78	18.68	9.50
18	6.02	6.02	12.14	12.06
42	4.32	5.38	22.04	20.06
90	3.82	5.12	22.50	23.60

[1]Scoring system--8 equals extremely tender, desirable flavor or juicy; 1 equals extremely tough, undesirable flavor or dry.
[2]Expressed in pounds, the greater the number of pounds the less tender the steak.

Color

Part 1

The three dimensions of color, in general, indicated that the _longissimus dorsi_ steaks became a darker red with increasing animal age. This agrees with the generally-accepted theory at the present regarding color and animal age.

The hue notation decreased significantly with advancing animal age (Table XII). This indicated that the loin steaks became a darker red as the animal age increased.

The value notation (brightness) of the steaks decreased with advancing animal age and increased during the 14-day aging period (Table XII). This suggests that steaks were darker from the older animals and lighter after aging 14 days. The value notation refers to the whiteness or gray-

TABLE XI

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE PALATABILITY FACTORS SHEAR VALUE, AND COOKING LOSS OF LONGISSIMUS DORSI STEAKS FROM ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

Source	d.f.	Panel Tenderness M.S.	Shear Value M.S.	Flavor M.S.	Juiciness M.S.	Cooking Loss M.S.
Total	39					
Age	3	69.37*	2805.73***	.97	13.00*	231.63
Animals[1]	16	13.85	311.21	.96	2.57	240.11
Aging	1	83.70***	642.60***	.00	3.20	196.00
Aging x Age	3	9.63*	530.87***	.20	1.83	80.37
Aging x Animals[2]	16	2.63	48.12	.71	1.36	104.09

* $p < 0.05$
*** $p < 0.005$

[1]Mean square used to test age.
[2]Mean square used to test aging.

TABLE XII

THE MEANS FOR THE TRISTIMULUS COLOR NOTATIONS OF LONGISSIMUS DORSI MUSCLE FROM ANIMALS OF THREE AGE GROUPS, TWO MARBLING LEVELS, AND TWO AGING PERIODS

Age (Months)	Hue	Value	Chroma
18	7.31R	4.01	7.43
42	6.20R	3.83	6.53
90	5.88R	3.56	6.13
Aging Days			
2	6.78R	3.61	6.33
14	6.15R	3.99	7.07
Marbling Level			
Sl. Amt.	6.40R	3.82	6.67
Sl. Abt.	6.53R	3.78	6.73

ness in a color (10 equals white and decreases through shades of grayness to 0 or black). It was observed that value increased or the steaks became a lighter and brighter red for almost every sample in the study which was aged 14 days. Doty (1956) also observed that aged rib-eye was lighter in color than unaged rib-eye. This dimension of color (value) appeared to influence the color of beef muscle more than the other two components.

The chroma notations decreased with advancing age and increased with aging 14 days. This means that the red color of the steaks was more intense from the younger animals and after being aged 14 days (Table XIII). Chroma did not react in the same manner for all age groups aged 14 days (Table XIV). Chroma from the steaks of 18-month animals decreased upon aging 14 days while for both the 42- and 90-month age groups it increased (Table XIII).

TABLE XIII

MUNSELL CHROMA MEANS SHOWING THE AGE X AGING INTERACTION

Age (Months)	2 Days Aging	14 Days Aging
18	8.05	6.81
42	5.85	7.21
90	5.08	7.19

Marbling in the steaks did not significantly influence any of the three dimensions of color (Table XIV). This agrees with the work of Hankins and Ellis (1939); however, it would appear that adding flecks of white fat to the red muscle should lighten the color or increase the value notation.

Part 2

The color of longissimus dorsi steaks appeared to be a darker red with increasing animal age, as was observed in Part 1.

When comparing steaks from all four age groups the hue notation approached significance as presented in Table XV; however, the means for each of the age groups revealed no particular pattern (Table XVI). In combination with the other two notations, however, it was possible to picture the darker red with increase in animal age.

The value notation was significantly related to both animal age and aging (Table XV). Steaks from the 6- and 18-month-old animals had similar value notation means; then from these there was a progressive decrease with increasing age (Table XVI). Aging the steaks 14 days again was associated with a significant increase in value or a lighter color (Table XVI).

TABLE XIV

ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE THREE DIMENSIONS OF COLOR OF THE *LONGISSIMUS DORSI* MUSCLE FROM THREE AGE GROUPS AT TWO MARBLING LEVELS AND TWO AGING PERIODS

Source	d.f.	Hue M.S.	Value M.S.	Chroma M.S.
Total	47			
Age	2	9.60***	.85**	7.08***
Marbling	1	.53	.01	.05
Age x Marbling	2	.95	.15	1.93
Animals[1]	18	.93	.08	.57
Aging	1	3.53	1.77***	6.59*
Aging x Marbling	1	.03	.03	2.01
Aging x Age	2	.73	.11	12.34***
Aging x Age x Marbling	2	2.70	.31	15.46***
Aging x Animals[2]	18	2.21	.09	.97

* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$
[1]Mean square used to test age and marbling.
[2]Mean square used to test aging.

TABLE XV

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE THREE DIMENSIONS OF COLOR OF THE LONGISSIMUS DORSI MUSCLE FROM FOUR AGE GROUPS AND TWO AGING PERIODS

Source	d.f.	Hue M.S.	Value M.S.	Chroma M.S.
Total	39			
Age	3	2.33	.28**	4.49*
Animals[1]	16	1.15	.05	1.00
Aging	1	1.42	1.21***	3.50
Aging x Age	3	2.55	.01	2.87
Aging x Animals[2]	16	1.22	.01	1.16

* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$

[1]Mean square used to test age.
[2]Mean square used to test aging.

TABLE XVI

THE MEANS FOR THE TRISTIMULUS COLOR NOTATIONS OF THE LONGISSIMUS DORSI MUSCLE FROM ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

Age (Months)	Hue	Value	Chroma
6	6.24R	3.95	6.05
18	7.03R	3.94	7.43
42	6.06R	3.92	6.43
90	5.97R	3.60	5.98
Aging Days			
2	6.51R	3.68	6.18
14	6.14R	4.03	6.77

Although the chroma notations for steaks were significantly related to animal age (Table XV), no particular pattern was observed for the means. Aging 14 days increased the chroma, i. e., caused a more intense red color in the longissimus dorsi steaks.

Expressible Fluids

Part 1

The total area (meat ring $\neq$ moisture ring) decreased significantly for those samples of beef aged 14 days as compared to those aged 2 days (Table XVII). This appears to be due, primarily, to the decrease in moisture ring area.

The meat area, significant for age groups, did not show an increase or decrease with advancing animal age (Table XVII). The meat area of the 18-month age group was the largest followed by the meat area for the 90-month animals. It is possible that the 1.5 percent greater fat content for the 18-month animals could have been related to the size of the meat area for that group. Hamm (1960) stated that the fine connective tissue of young animals will swell and retain water better than that of older animals. This may also help to explain the larger meat area for the 18-month age group.

Although the meat ring areas were not significantly different for marbling, the mean for the "slightly abundant" level was .20 inch larger than the mean for the "slight amount" level (Table XVII).

TABLE XVII

EXPRESSIBLE FLUID MEANS FROM THE *LONGISSIMUS DORSI* MUSCLE OF THREE AGE GROUPS, TWO MARBLING LEVELS, AND TWO AGING PERIODS[1]

Age (Months)	Area[a]	Area[b]	Area[c]	Ratio[d]
18	11.14	4.51	6.69	1.49
42	10.63	4.11	6.53	1.62
90	11.00	4.24	6.78	1.61
Aging Days				
2	11.07	4.32	6.79	1.59
14	10.78	4.25	6.55	1.56
Marbling Level				
Sl. Amt.	11.07	4.19	6.91	1.67
Sl. Abt.	10.78	4.39	6.43	1.48

[1]Area in square inches
[a]Meat ring ≠ plus moisture ring
[b]Meat ring
[c]Moisture ring
[d]Moisture ring to meat ring

Marbling and aging were significantly associated with the moisture ring areas (Table XVIII). Aging beef 14 days or increasing the marbling

TABLE XVIII

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR EXPRESSIBLE FLUID DATA FROM THE LONGISSIMUS DORSI MUSCLE OF THREE AGE GROUPS, TWO MARBLING LEVELS, AND TWO AGING PERIODS

Source	d.f.	Area[a] M.S.	Area[b] M.S.	Area[c] M.S.	Ratio[d] M.S.
Total	47				
Age	2	11.20	6.80*	2.50	.94
Marbling	1	9.60	4.80	28.10**	4.51*
Age x Marbling	2	5.50	1.10	4.75	.85
Animals[1]	18	3.83	1.71	3.27	.54
Aging	1	9.60*	.50	7.00**	.05
Aging x Marbling	1	.60	1.00	.40	.11
Aging x Age	2	2.65	1.75	2.00	.31
Aging x Age x Marbling	2	.20	.10	.65	.06
Aging x Animals[2]	18	1.77	1.25	.73	.19

* $p < 0.05$
** $p < 0.01$
[a]Meat ring plus moisture ring.
[b]Meat ring.
[c]Moisture ring.
[d]Moisture ring to meat ring.
[1]Mean Square used to test age and marbling.
[2]Mean Square used to test aging

level decreased the moisture ring areas (Table XVII). Wanderstock and Miller (1948) and Gaddis et al. (1950), although not using the same technique, also observed less expressible fluid with increased fatness.

This may be due to the decrease in percentage of moisture with increase in fat or an influence which fat may have on the release of moisture from tissue under pressure. The decreased moisture area during the 14-day aging agrees with Hamm's observation (1960), that a slow increase in hydration of meat occurred during the resolution of rigor. He also stated that the water-holding capacity of meat was not correlated with its total moisture content. The results of this study show somewhat the same trend, in that, the average moisture area for the 42-month age group was the lowest for the three age groups and the percentage of moisture in the proximate analysis was the highest.

The moisture ring to meat ring ratio was significantly smaller for the 18-month age group than for the two older groups (Table XVII). This means that for the youngest age group the moisture ring in relation to the meat ring was smaller.

Part 2

Animal age was significantly associated with the total area (meat ring + moisture ring) when considering all four age groups (Table XIX). However, the means are of little aid in interpreting these results (Table XX). The 6-month age group had the largest area, but no pattern formed after that with regard to age.

The meat ring area decreased in size from the 6- to 42-month age group, then a slight increase was shown for the 90-month age group (Table XX). The 18-, 42- and 90-month age groups presented approximately the same pattern as in Part 1. Since muscle tissue from the calves was

TABLE XIX

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR EXPRESSIBLE FLUID DATA FROM THE *LONGISSIMUS DORSI* MUSCLE OF FOUR AGE GROUPS AND TWO AGING PERIODS

Source	d.f.	Area[a] M.S.	Area[b] M.S.	Area[c] M.S.	Ratio[d] M.S.
Total	39				
Age	3	14.40*	7.97*	4.03	1.27
Animals[1]	16	4.36	2.11	4.09	.69
Aging	1	.90	.40	3.40*	.16
Aging x Age	3	2.43	1.83	3.67*	.54
Aging x Animals[2]	16	1.57	1.09	.95	.20

* $p < 0.05$
[a]Meat ring plus moisture ring.
[b]Meat ring.
[c]Moisture ring.
[d]Moisture ring to meat ring.
[1]Mean square used to test age.
[2]Mean square used to test aging

normally softer and the "structural make-up" not as firm as in the older animals, it would seem logical that the meat areas would be larger.

TABLE XX

EXPRESSIBLE FLUID MEANS FROM THE LONGISSIMUS DORSI MUSCLE OF FOUR AGE GROUPS AND TWO AGING PERIODS[1]

Age (Months)	Area[a]	Area[b]	Area[c]	Ratio[d]
6	11.49	4.57	6.93	1.53
18	11.22	4.40	6.91	1.56
42	10.61	3.93	6.67	1.74
90	11.29	4.14	7.16	1.74
Aging Days				
2	11.20	4.23	7.01	1.66
14	11.11	4.29	6.83	1.62

[1]Area in square inches.
[a]Meat ring plus moisture ring.
[b]Meat ring.
[c]Moisture ring.
[d]Moisture ring to meat ring.

The size of the moisture ring area was not significantly related to animal age (Table XIX). There was 3.5 percent difference in total moisture between the 6- and 90-month age groups, but little difference in moisture ring areas (Table XX). From this it would appear that there may be differences in the water-binding capacity of the various age groups. The pH of muscle has also been associated with its water-holding capacity and it should be pointed out that the pH for the 90-month age group was 5.26 as compared to 5.61 for the 6-month age group. The pH for the 90-month animals, being close to the isoelectric point for muscle protein, should have less water-binding capacity than muscle from the 6-month calves. Possibly there was a difference in their water-binding capacities and the extreme difference in total moisture caused the areas to be similar.

Aging the meat 14 days, as observed in Part 1, significantly decreased the moisture ring area (Table XIX). The means, however, show that aging 14 days did not give the same results for all groups (Table XXI). Samples from the 18-month age group and aged 14 days showed by far the greatest decrease in moisture ring area (Table XXI). This increase in apparent "hydration" of the meat could not be attributed to pH since there actually was a drop rather than a rise in pH for this age group. The 6- and 90-month groups showed slight decreases in moisture area and the 42-month group an increase.

TABLE XXI

THE MOISTURE RING AREAS IN SQUARE INCHES DISPLAYING THE AGING X AGE INTERACTION

Aging Days	6	18	42	90
2	6.98	7.28	6.60	7.18
14	6.88	6.54	6.74	7.14

The moisture ring to meat ring ratios were divided into two distinct pairs, the ratios for the 6- and 18-month age groups were similar and the 42- and 90-month ratios were the same (Table XX). The significant break occurred between the 18- and 42-month age groups. A number of factors may account for the smaller ratios observed in the younger age groups. A higher pH and looser "structural make-up" of the muscle tissue may give a larger meat ring and a smaller moisture ring. The greater percentage of connective tissue in young muscle, observed by Wilson et al. (1954), and the greater water-holding capacity of connective tissue compared to muscle tissue, noted by Hamm (1960), may also give cause for greater "hydration" of meat from young animals.

Chemical Composition

Part 1

pH--There was a significant decrease in pH with advancing animal age as observed on the *longissimus dorsi* steaks (Table XXIV). An increase of .14 pH units was noted from the 2-day to 14-day aging period. This increase in pH during aging was also reported by Paul (1943), Arnold et al. (1956), and Doty (1956). The results of this study also revealed that the increase in pH during the 14-day aging was inconsistent for both marbling levels (Table XXII). The increase in pH took place predominantly in the lower marbling level; the "slightly abundant" level presented little change to a slight decrease in pH during the 14-day aging (Table XXII). Steaks aged 14 days from the 42- and 90-month age groups also displayed a greater increase in pH than the 18-month age group (Table XXIII).

TABLE XXII

THE MEANS DISPLAYING THE AGING X MARBLING INTERACTION OF pH

Aging Days	Sl. Amt.	Sl. Abt.
2	5.19	5.45
14	5.48	5.43

Moisture--The three age groups studied did not differ significantly in total moisture in the *longissimus dorsi* muscle (Table XXV). The moisture content was, however, significantly lower for the "slightly abundant" as compared to the "slight amount" marbling level (Table XXIV). All samples aged 14 days also decreased significantly in percent moisture (Table XXIV).

TABLE XXIII

THE MEANS DISPLAYING THE AGING X AGE INTERACTION OF pH

	Age (Months)		
Aging Days	18	42	90
2	5.54	5.28	5.15
14	5.44	5.54	5.40

Ash--As was expected, ash did not vary significantly with regards to animal age, marbling level or aging period.

Ether Extract-- The fat content did not differ significantly among age groups. Little variation in fat content was an objective in this analysis. Since the animals were selected for the "slightly abundant" and "slight amount" marbling levels the significant difference observed between marbling levels for ether extract was not surprising. The difference in ether extract between the 2- and 14-day aging periods was non-significant, which indicated that the right and left sides were not significantly different in fat content (Table XXV). The difference, however, between the means for both sides of the longissimus dorsi muscle was .41 percent, the right side containing the greater amount of fat (Table XXIV).

Protein--There was a slight but non-significant increase in protein noted with increasing animal age (Table XXIV). The difference in protein between marbling levels was approaching significance at the .05 probability level. The "slight amount" level exhibited a higher percent-

TABLE XXIV

THE MEANS FOR THE CHEMICAL ANALYSES OF THE *LONGISSIMUS DORSI* MUSCLE SAMPLED AT TWO DIFFERENT AGING PERIODS FROM CATTLE OF THREE AGE GROUPS AND TWO MARBLING LEVELS

Age (Months)	pH	Moisture[1]	Ash[1]	Ether Extract[1]	Protein[1]
18	5.49	68.71	1.03	8.59	21.29
42	5.41	69.25	1.04	7.06	21.51
90	5.28	68.82	1.04	7.16	21.61
Aging Days					
2	5.32	69.49	1.05	7.40	21.25
14	5.46	68.36	1.02	7.81	21.69
Marbling Level					
Sl. Amt.	5.34	69.80	1.05	6.48	21.67
Sl. Abt.	5.44	68.05	1.03	8.73	21.27

[1]Expressed in percent.

TABLE XXV

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE CHEMICAL ANALYSES OF THE LONGISSIMUS DORSI MUSCLE SAMPLED AT TWO AGING PERIODS FROM CATTLE OF THREE AGE GROUPS AND TWO MARBLING LEVELS

Source	d.f.	pH M.S.	Moisture M.S.	Ash M.S.	Ether Extract M.S.	Protein M.S.
Total	47					
Age	2	1.80*	13.20	.00	117.85	4.40
Marbling	1	1.30	367.50*	.00	603.00***	19.60
Age x Marbling	2	.10	104.65	.05	57.10	.45
Animals[1]	18	.42	46.69	.05	45.66	4.74
Aging	1	2.20*	154.10**	.10	20.80	23.80**
Aging x Marbling	1	2.90**	24.30	.10	8.60	.90
Aging x Age	2	1.75*	4.75	.05	.35	7.00
Aging x Age x Marbling	2	1.05	1.65	.00	.00	3.50
Aging x Animals[2]	18	.32	17.67	.03	10.30	2.42

* $p < 0.05$
** $p < 0.01$
*** $p < 0.005$
[1]Mean square used to test age and marbling.
[2]Mean square used to test aging.

age of protein than the "slightly abundant" level (Table XXIV). A significant increase in the protein of beef was observed by increasing the aging period from 2 to 14 days (Table XXIV).

Part 2

pH--The influence of animal age on the pH of longissimus dorsi steaks was not significant at the 0.10 probability level (Table XXVI). However, the means show a decrease in pH with increasing animal age (Table XXVII). A significant increase of .24 pH units was observed from the 2- to 14-day aging period (Table XXVII). This pH increase accompanying the 14-day aging was noted for all age groups, except the 18-month animals and they decreased slightly in pH (Table XXVIII,a).

Moisture--A significant difference in moisture was observed for animal age (Table XXVI). The loin muscle of the 6-month animals contained 72.63 percent moisture as compared to 68.92 percent for the 90-month age group. Little difference in moisture was noted between the 18- and 42-month age groups (Table XXVII). A significant decrease in moisture was again revealed after aging the muscle 14 days (Table XXVII).

Ash--The ash content was not significantly associated with any of the factors studied, although the 6-month age group did show the highest percentage.

Ether Extract--When Analysis II was outlined it was the desire to have animals of approximately the same marbling level and percentage of ether extract. The significant difference obtained between age groups and ether extract was readily apparent from the means (Table XXVII). The difference between the high and low of 2.61 percent was greater than the difference between the two marbling levels in Analysis I.

TABLE XXVI

THE ANALYSES OF VARIANCE SHOWING THE MEAN SQUARES FOR THE CHEMICAL ANALYSES OF THE LONGISSIMUS DORSI MUSCLE SAMPLED AT TWO AGING PERIODS FROM ANIMALS OF FOUR AGE GROUPS

Source	d.f.	pH M.S.	Moisture M.S.	Ash M.S.	Ether Extract M.S.	Protein M.S.
Total	39					
Age	3	2.07	234.47***	.07	151.47*	5.40
Animals[1]	16	.96	30.99	.03	30.41	4.66
Aging	1	5.50***	152.50*	.00	27.00	8.70*
Aging x Age	3	2.33***	10.33	.03	.17	8.77***
Aging x Animals[2]	16	.35	19.11	.02	10.32	1.24

* $P < 0.05$
*** $p < 0.005$
[1]Mean square used to test age.
[2]Mean square used to test aging.

TABLE XXVII

THE MEANS FOR THE CHEMICAL ANALYSES OF THE *LONGISSIMUS DORSI* MUSCLE SAMPLED AT TWO AGING PERIODS FROM CATTLE OF FOUR AGE GROUPS

Age (Months)	pH	Moisture[1]	Ash[1]	Ether Extract[1]	Protein[1]
6	5.61	72.63	1.10	4.25	21.24
18	5.46	70.30	1.03	6.86	21.55
42	5.42	70.58	1.07	5.06	21.76
90	5.26	68.92	1.05	6.53	21.70
Aging Days					
2	5.32	71.23	1.08	5.42	21.42
14	5.56	69.99	1.05	5.94	21.71

[1]Expressed in percent.

TABLE XXVIII

THE MEANS DISPLAYING THE AGING X AGE INTERACTION FOR pH AND PROTEIN

a. pH

	Age (Months)			
Aging Days	6	18	42	90
2	5.52	5.54	5.24	4.98
14	5.70	5.38	5.60	5.54

b. Protein

2	21.22	21.68	21.62	21.14
14	21.26	21.42	21.90	22.26

Protein--The protein content of the longissimus dorsi muscle showed a slight but non-significant increase up to the 42-month age group then a very slight decrease for the 90-month age group. Aging the muscle 14 days significantly increased the protein from 21.42 percent for the 2-day sample, to 21.71 for the 14-day sample. This aging increase could be attributed mainly to the increase observed in the 90-month age group (Table XXVIII,b).

The Interrelationships of the Various Factors Studied

It should be pointed out that the degrees of freedom are different for each age group, hence, the level of significance changes accordingly. The means and standard deviations for each age group for all factors studied are shown in Tables XXXV to XXXVIII in the Appendix.

Correlation coefficients between taste panel tenderness and factors associated with meat palatability and hydration are presented in Table XXIX.

The negative correlations between panel tenderness and the Warner-Bratzler shear varied widely among age groups. Those for the 42- and 90-month age group were non-significant while the correlations for the 6, 18, and pooled age groups were much higher and significant at the .01 and .05 probability levels. The association between these two estimators of tenderness was higher for samples aged 2 days than for those aged 14 days. This may be due to the fact that aging 14 days decreased the variability observed at 2 days. Deatherage and Garnatz (1952) attributed the low, non-significant correlations they obtained in comparing panel tenderness and the Warner-Bratzler shear to the small variation in the tenderness of steaks sampled.

TABLE XXIX

CORRELATION COEFFICIENTS BETWEEN PANEL TENDERNESS AND FACTORS ASSOCIATED WITH MEAT PALATABILITY AND HYDRATION FROM THE LONGISSIMUS DORSI MUSCLE OF BEEF ANIMALS

Age (Months)	d.f.	Shear value	Moisture Ring Area	Meat Ring Area	Panel Flavor	Panel Juiciness
2 Days' Aging						
6	14	-.818**	-.539*	-.267	+.275	+.160
18	10	-.903**	-.533	+.306	+.435	+.313
42	11	-.408	-.377	-.218	+.831**	+.669*
90	13	-.479	-.327	+.024	+.479	+.413
Pooled	54	-.720**	-.059	+.052	+.528**	+.273*
14 Days' Aging						
6	14	-.631**	-.409	+.161	+.587*	+.576*
18	10	-.692*	-.635*	+.511	+.264	+.293
42	11	-.361	-.054	-.222	+.805**	+.963**
90	13	-.161	-.579*	-.520*	+.241	+.532*
Pooled	54	-.618**	-.138	+.312*	+.410**	+.481

* $p < 0.05$
** $p < 0.01$

The correlations between moisture ring area and panel tenderness, in general, were low, but all negative. This is an indication that those samples with the smallest moisture areas were the most tender. The correlations between meat ring and panel tenderness were low, and variable with regard to sign.

Flavor and juiciness, when associated with panel tenderness, displayed a wide range of positive correlation coefficients with all pooled relationships being significant at the .01 or .05 level. In general, this may indicate that when a taste panel member scores tenderness high, the chances are that flavor and juiciness will also be scored fairly high.

The correlation coefficients comparing marbling with the various palatability factors are shown in Table XXX.

It was interesting to note that of the correlations between panel tenderness and marbling, only those steaks sampled at 2 days from the 90-month age group were significantly related. All other correlations between marbling and panel tenderness were low and inconsistent with regard to sign. Shear values when compared with marbling level displayed a wide variation in correlation coefficients which were variable with regard to sign. However, the shear values for the 90-month age group at both aging periods and the 6-month group at 2 days aging were significantly, negatively, related to marbling. This means that increased marbling for those animals tended to produce more tender steaks. Generally it appears that marbling may be more closely associated with the tenderness of old cows than the younger animals. Flavor and juiciness were not associated with marbling at any age level, with the exception of possibly the 18-month age group. The correlation coefficients

TABLE XXX

CORRELATION COEFFICIENTS COMPARING MARBLING WITH THE PALATABILITY FACTORS AND SHEAR VALUE FROM THE *LONGISSIMUS DORSI* MUSCLE OF BEEF ANIMALS

Age (Months)	d.f.	Panel Tenderness	Shear Value	Panel Flavor	Panel Juiciness
2 Days' Aging					
6	14	-.295	+.105	+.084	
18	10	+.187	+.060	+.314	+.304
42	11	+.179	-.275	+.004	-.162
90	13	+.608*	-.608*	+.165	-.087
Pooled	54	+.029	-.221	+.150	+.006
14 Days' Aging					
6	14	+.378	-.618*	-.040	+.131
18	10	+.207	-.142	+.546	+.712**
42	11	-.055	-.453	+.089	-.079
90	13	-.039	-.669**	+.158	-.218
Pooled	54	-.228	-.035	+.200	+.077

* $p < 0.05$
** $p < 0.01$

between marbling level and flavor and juiciness for this age group were higher than for the other ages and significant in one instance.

The correlation coefficients between ether extract and various quality and palatability factors are shown in Table XXXI.

Marbling and ether extract were closely related for all ages and age groups, except the 42-month animals. The correlations for this group were much lower than the others and non-significant in one instance. Normally, if both estimators are accurate the relationships are expected to be high. However, some variation might be anticipated since ether extract was determined at an area a few inches posterior to the 12th rib. Unpublished work by Walker (1960), revealed an anterior to posterior increase in percentage of fat along the longissimus dorsi muscle in the wholesale loins.

The one positive, significant correlation between panel tenderness and ether extract was for the 90-month age group sampled at 2 days. Flavor and juiciness of the 18-month-old animals were again more closely related to ether extract than any of the other age groups. Essentially no other significant relationships were noted between shear values, panel tenderness, juiciness, flavor and ether extract. These data suggest that ether extract or marbling are not as closely related to the palatability factors as some reports in the literature indicate.

The correlation coefficients between the Munsell value notations and the various quality and chemical characteristics are shown in Table XXXII.

The pooled age group was significantly, positively correlated with panel tenderness. Since previously in this study a decrease in tenderness and a decrease in the value notation with advancing age was observed,

TABLE XXXI

CORRELATION COEFFICIENTS COMPARING ETHER EXTRACT WITH THE QUALITY AND PALATABILITY FACTORS FROM THE LONGISSIMUS DORSI MUSCLE OF BEEF ANIMALS

Age (Months)	d.f.	Marbling Score	Panel Tenderness	Shear Value	Panel Flavor	Panel Juiciness
2 Days' Aging						
6	14	+.788**	-.464	+.362	+.032	-.115
18	10	+.772**	+.147	+.049	+.399	+.504
42	11	+.537*	+.093	-.219	+.092	-.216
90	13	+.770**	+.628*	-.372	+.165	+.313
Pooled	54	+.815**	+.038	-.226	+.223	+.107
14 Days' Aging						
6	14	+.801**	+.228	-.419	-.070	+.040
18	10	+.788**	+.121	-.047	+.543	+.748**
42	11	+.535	-.120	-.279	-.050	-.063
90	13	+.728**	-.007	-.446	+.106	+.003
Pooled	54	+.814**	-.217	+.021	+.197	+.093

* $p < 0.05$
** $p < 0.01$

TABLE XXXII

CORRELATION COEFFICIENTS BETWEEN THE MUNSELL VALUE NOTATIONS AND THE QUALITY AND CHEMICAL CHARACTERISTICS OF THE LONGISSIMUS DORSI MUSCLE FROM BEEF ANIMALS

Age (Months)	d.f.	Panel Tenderness	Shear Value	pH	Marbling Score	Ether Extract
2 Days' Aging						
6	14	+.095	-.105	-.653**	+.250	+.186
18	10	-.190	+.235	-.039	-.015	+.189
42	11	-.251	-.079	-.269	-.014	+.052
90	13	+.218	-.141	-.164	+.191	+.320
Pooled	54	+.299*	-.248	+.249	-.177	-.089
14 Days' Aging						
6	14	-.034	-.189	-.053	+.463	+.307
18	10	+.151	-.255	+.162	+.701*	+.320
42	11	-.239	+.104	+.293	-.311	+.206
90	13	-.018	-.260	+.265	+.326	+.453
Pooled	54	+.343**	-.559**	+.193	+.011	+.097

* $p < 0.05$
** $p < 0.01$

this relationship might be expected.

The other correlations between the value notation and shear, pH marbling, and ether extract were generally low and non-significant.

SUMMARY

The influence of animal age, marbling, and length of aging period on the palatability and the physical and chemical characteristics of beef was investigated. The _longissimus_ _dorsi_ muscle from the short loin of 56 Hereford steers and females, 6, 18, 42, and 90 months of age was used for this study. The animals were of a uniform genetic background and received similar nutrition and management treatment. Predominantly, the marbling of each carcass was or closely approached either a "slight amount" or "slightly abundant" level.

The tenderness of _longissimus_ _dorsi_ steaks decreased significantly with increasing animal age as measured by the Warner-Bratzler shear values and a panel evaluation of tenderness. The greatest difference in tenderness was observed between the 18- and 42-month age groups. Animals 18-months and younger were very tender while those 42-months and older were approaching the slightly tough state.

The association of marbling with tenderness varied with animal age. Increased marbling did not enhance the tenderness of 18-month-old animals; however, it was related to an increase in tenderness of steaks from the 42- and 90-month age groups.

The results of aging varied with animal age, marbling level and the tenderness measure used. In general, aging for 14 days appeared to have the greatest influence on the 6-month calves followed by the 42- and 90-month-old cows. Steak from the 18-month-old animals changed little in tenderness during the 14-day aging.

Taste panel flavor and juiciness scores were associated only slightly with animal age, marbling level or aging 14 days.

The three components of color indicated that the longissimus dorsi steaks became a darker red with advancing animal age and tended to be a lighter, brighter red after aging 14 days. Of the three components, the Munsell value notation seemed to have the most influence on the color of meat.

The moisture ring areas were significantly associated with marbling and aging. As the marbling level and aging period increased, the moisture areas decreased. The moisture ring to meat ring ratios were divided into two distinct pairs. The 6- and 18-month age ratios were much smaller than those for the 42- and 90-month-old animals. The meat rings, in general, were larger for the younger animals than for the older animals, with little difference noted in the moisture ring areas. The correlation coefficients between moisture ring area and panel tenderness were low, but all negative, which indicated that those samples with the smallest moisture areas were the most tender.

The pH decreased with advancing animal age and increased during the 14-day aging. The increase in pH noted with aging 14 days took place predominantly in the "slight amount" marbling level of the 42- and 90-month-old cattle.

Moisture content differed little among the 18-, 42-, and 90-month-old cattle but was higher for the 6-month-old calves.

The relationship between the Warner-Bratzler shear and panel tenderness varied widely among age groups. The association was much closer for the 6- and 18-month ages than for the 42- and 90-month ages.

The results of this study indicated that many changes occur in beef muscle with advancing animal age, some being undesirable with regard to palatability. The greatest change, in most instances, appeared between the 18- and 42-month age groups. Further study using animals which thoroughly cover the age range of 42 months and under is needed to indicate more precisely the age at which these changes take place.

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APPENDIX

TABLE XXXIII

INDIVIDUAL CARCASS INFORMATION

6-Month Age

ANIMAL NO.	CLASS	GRADE	MARBLING	MATURITY LEVEL	COLD CARCASS WT.
025	calf (H)	prime-	modest	A	300
945	calf (S)	choice	Sl. Amt.	A	344
215	calf (H)	choice	Sl. Amt.	A	309
944	calf (S)	choice	Sl. Amt.	A	362
093	calf (H)	choice-	Traces+	A	307
059	calf (H)	choice-	Traces+	A	240
030	calf (H)	choice-	Traces+	A	298
886	calf (H)	good	Traces	A	231
013	calf (H)	good+	Traces	A	312
036	calf (H)	good+	Traces	A	284
015	calf (H)	choice-	Traces	A	273
027	calf (H)	good	Traces-	A	314
053	calf (S)	choice-	Traces	A	312
874	calf (H)	good	Prac. Dev.	A	279
876	calf (H)	good	Prac. Dev.	A	265
881	calf (H)	standard+	Prac. Dev.	A	203

(H) = Heifer
(S) = Steer

18-Month Age

ANIMAL NO.	CLASS	GRADE	MARBLING	MATURITY LEVEL	COLD CARCASS WT.
4938	steer	prime-	Sl. Abt.	A	694
3933	steer	choice+	Sl. Abt.	A	655
4560	steer	prime-	Sl. Abt.	A	600
3660	steer	prime-	Sl. Abt.	A	608
909	heifer	choice+	Sl. Abt.	A	490
60	steer	good+	Sl. Amt.+	A+	577
62	steer	good+	Sl. Amt.	A	477
74	steer	good	Sl. Amt.+	B-	550
942	heifer	good+	Sl. Amt.+	A	498
941	steer	good+	Sl. Amt.+	A+	710
5760	steer	good+	Sl. Amt.+	A+	542
993	steer	good+	Sl. Amt.+	A	676

TABLE XXXIV

INDIVIDUAL CARCASS INFORMATION

ANIMAL NO.	CLASS	GRADE	MARBLING	MATURITY LEVEL	COLD CARCASS WT.
			42-Month Age		
157	heifer	choice-	Sl. Abt.	C	836
719	heifer	choice-	Sl. Abt.	C	686
267	heifer	choice-	Moderate	C	950
527	heifer	choice-	Moderate	C	906
125	cow	comm.	Modest	D	714
445	cow	comm.-	Sm. Amt.	D	808
107	heifer	comm.-	Sm. Amt.	D	733
717	heifer	good-	Sm. Amt.	C	724
337	heifer	comm.-	Sm. Amt.	D	917
387	heifer	good-	Sm. Amt.	C	799
733	heifer	utility+	Sl. Amt.	D	715
296	heifer	good-	Sl. Amt.	B	670
236	cow	utility+	Sl. Amt.	D	786
515	cow	utility+	Sl. Amt.	D-	616
295	cow	utility+	Sl. Amt.	D	655
			90-Month Age		
313	cow	comm.+	Mod. Abt.	F	963
670	cow	comm.	Sl. Abt.	F	819
233	cow	comm.-	Moderate	F	1036
503	cow	comm.-	Moderate-	F	830
753	cow	comm.-	Moderate	F	935
683	cow	comm.-	Moderate	F	913
903	cow	comm.-	Moderate	F	855
401	cow	utility+	Sm. Amt.+	F	651
801	cow	utility+	Sm. Amt.	F	789
791	cow	utility	Sl. Amt.	F	736
311	cow	utility+	Sl. Amt.	F	866
731	cow	utility+	Sl. Amt.	F-	694
612	cow	utility+	Sl. Amt.	E+	750
262	cow	utility+	Sl. Amt.	E+	818
802	cow	utility	Sl. Amt.	E+	659
592	cow	utility	Sl. Amt.	F	605
662	cow	utility	Sl. Amt.	F	931

TABLE XXXV

THE MEANS AND STANDARD DEVIATIONS FOR THE PALATABILITY CHARACTERISTICS OF THE LONGISSIMUS DORSI MUSCLE FROM 56 ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

Animal Age in Months	Panel[1] Tenderness Mean	Panel[1] Tenderness S. D.	Panel[1] Flavor Mean	Panel[1] Flavor S.D.	Panel[1] Juiciness Mean	Panel[1] Juiciness S.D.	Shear[2] Force Mean	Shear[2] Force S.D.	Cooking[3] Loss Mean	Cooking[3] Loss S.D.
2 Days' Aging										
6	5.49	1.00	6.00	0.24	5.27	0.47	19.44	4.12	26.94	3.66
18	6.17	0.96	6.20	0.43	5.13	0.71	11.80	3.97	28.97	4.97
42	4.53	1.04	5.91	0.51	5.04	0.96	19.45	3.29	33.08	3.40
90	4.45	0.91	6.03	0.34	5.54	0.66	20.78	4.08	34.14	5.50
14 Days' Aging										
6	6.58	0.62	6.09	0.30	5.33	0.61	11.74	2.78	25.79	4.39
18	6.25	0.70	6.32	0.19	5.11	0.61	11.28	2.53	29.93	3.72
42	5.05	1.17	6.01	0.46	5.23	0.94	17.02	3.66	31.29	3.55
90	5.27	0.66	6.30	0.44	5.55	0.64	19.11	4.28	32.55	3.18

[1]Scoring system -- 8 equals extremely tender, desirable flavor or juicy; 1 equals extremely tough, undesirable flavor or dry.

[2]Expressed in pounds, the greater the number of pounds the less tender the steak.

[3]Expressed as a percent of the precooked weight.

TABLE XXXVI

THE MEANS AND STANDARD DEVIATIONS FOR EACH OF THE THREE DIMENSIONS OF COLOR OF THE LONGISSIMUS DORSI MUSCLE FROM 56 ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

Age (Months)	Tristimulus Color Notations: Hue Mean	Hue S.D.	Value Mean	Value S.D.	Chroma Mean	Chroma S.D.
2 Days' Aging						
6	5.91R	1.71	3.80	0.19	5.34	0.88
18	7.34R	1.65	3.78	0.25	7.44	1.99
42	6.19R	1.26	3.60	0.25	5.54	1.02
90	6.34R	1.54	3.40	0.20	5.90	1.10
14 Days' Aging						
6	6.57R	1.13	4.18	0.20	6.30	0.87
18	6.83R	0.90	4.31	0.17	6.87	0.52
42	5.95R	0.72	3.88	0.17	7.28	0.47
90	5.87R	0.64	3.79	0.28	7.25	0.60

TABLE XXXVII

THE MEANS AND STANDARD DEVIATIONS OF THE EXPRESSIBLE FLUID CHARACTERISTICS OF THE LONGISSIMUS DORSI MUSCLE FROM 56 ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

Age (Months)	Area[1] Mean	Area[1] S.D.	Area[2] Mean	Area[2] S.D.	Area[3] Mean	Area[3] S.D.	Ratio[4] Mean	Ratio[4] S.D.
2 Days' Aging								
6	11.23	0.59	4.28	0.36	6.93	0.51	1.63	0.20
18	11.42	0.46	4.40	0.29	7.11	0.52	1.61	0.16
42	10.63	0.69	4.20	0.44	6.43	0.53	1.55	0.23
90	10.66	0.85	4.18	0.48	6.50	0.60	1.57	0.20
14 Days' Aging								
6	11.29	0.72	4.62	0.34	6.69	0.62	1.46	0.18
18	11.04	0.30	4.41	0.44	6.64	0.41	1.53	0.23
42	10.46	0.70	3.99	0.51	6.48	0.49	1.65	0.27
90	10.26	0.96	3.89	0.41	6.39	0.66	1.65	0.15

[1]Meat ring plus moisture ring.
[2]Meat ring.
[3]Moisture ring.
[4]Moisture ring to meat ring.

TABLE XXXVIII

THE MEANS AND STANDARD DEVIATIONS FOR VARIOUS CHEMICAL CHARACTERISTICS OF THE LONGISSIMUS DORSI MUSCLE FROM 56 ANIMALS OF FOUR AGE GROUPS AND TWO AGING PERIODS

2 Days' Aging

Age	pH		Moisture[1]		Ash[1]		E. Extract[1]		Protein[1]	
(Months)	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
6	5.50	0.16	73.20	0.90	1.11	0.05	3.41	1.24	21.54	0.48
18	5.58	0.23	69.04	2.67	1.05	0.08	8.13	3.12	21.28	0.78
42	5.29	0.21	69.77	1.64	1.06	0.07	6.82	1.70	21.43	0.58
90	5.16	0.16	69.21	1.46	1.05	0.05	7.15	1.79	21.25	0.58

14 Days' Aging

Age (Months)	pH Mean	pH S.D.	Moisture Mean	Moisture S.D.	Ash Mean	Ash S.D.	E. Extract Mean	E. Extract S.D.	Protein Mean	Protein S.D.
6	5.61	0.35	72.54	0.99	1.09	0.06	3.77	1.53	21.46	0.80
18	5.37	0.24	68.40	2.47	1.00	0.00	8.53	2.43	21.33	0.48
42	5.45	0.20	68.99	1.65	1.03	0.05	7.02	1.61	21.85	0.71
90	5.33	0.24	68.24	1.94	1.03	0.06	7.63	2.33	21.67	0.83

[1]Expressed in percent.

VITA

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Doctor of Philosophy

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