THE EFFECT OF ANIMAL AGE ON PALATABILITY FACTORS IN BEEF

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Bachelor of Science

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Stillwater, Oklahoma

1956

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1965

THE EFFECT OF ANIMAL AGE ON PALATABILITY FACTORS IN BEEF

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ACKNOWLEDGMENT

The author wishes to express appreciation to Dr. Robert L. Henrickson of the Animal Science Department, under whose assistance and guidance this thesis was made.

Grateful acknowledgment is also extended to Dr. Lowell E. Walters, Dr. Helen F. Barbour and Roger W. Mandigo for their cooperation and suggestions during the preparation of this thesis.

Appreciation is extended to the Fort Reno Experiment Station for the management of the cattle; the Oklahoma Packing Company for use of facilities for slaughtering the animals; and to the Federal Grading Service for effort in establishing the carcass grade Recognition is also given to the Departments of Biochemistry and Statistics at Oklahoma State University for their cooperation, advice and use of facilities.

The author is indebted to the technical research staff and graduate students of the Meat Laboratory during the years of 1959-1964 for their assistance and suggestions.

The writer wishes to express her sincere appreciation to her husband, Norman, and daughters, Michelle, Janna and Shirlene, for their continuous encouragement throughout this program of graduate study.

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INTRODUCTION

To furnish to the consumer a product that is wholesome, nutritive and palatable is the prime goal of the meat industry. Those engaged in formulating standards must remember the consumer and evaluate all criteria concerned in an acceptable meat product.

The consumer appears to desire a maximum of tenderness combined with a particular ideal for juiciness, aroma, flavor and texture of beef. These desired palatability characteristics are often referred to as meat quality. Perhaps no single term used in connection with food has as many connotations as the word quality. Quality may be defined as "the summation of distinctive traits or special features that determine the ultimate acceptability of the product to the consumer" (Doty, 1959). It refers to a combination of physical, structural and chemical characteristics which result in maximum desirability of appearance and palatability.

Quality in fresh meat is measured visually by several physical characteristics such as age of the animal (as indicated by the nature of the bone), color of fat and lean, firmness of fat and lean, texture of lean and amount of marbling or internal fat. To perform a useful service in the marketing process, meat grading must be based on those factors that are important to buyers and sellers and which affect the utility of the product (Pierce, 1959). These quality criteria or official grades are designed to standardize beef and are expected to indicate to the user the palatability factors of tenderness, flavor and juiciness.

Palatability is influenced by many interrelated factors. These include the genetic factors of breed and sex; environmental factors, including feeding, management, exercise and stress; and physiological factors, as sex and age of the animal. Other related factors include those that are chemical and microbiological in nature, for example, the period and condition of aging of the raw meat. The histological and anatomical factors include muscle variation within the animal and also variation within the muscle, the amount and nature of connective tissue (both collagen and elastin), the size of muscle fibers, the fatness of the animal as indicated by finish and intramuscular fat (marbling). Palatability is affected by processing factors, the method of cutting, storing and cooking; and finally, the method of evaluation, whether mechanical, sensory or chemical. The comparative influence on palatability of these factors, alone and in combination, are not well understood.

The objectives of this study were to evaluate 1) the influence of bovine age on the shear, panel tenderness, juiciness and flavor of the meat, 2) the influence of the inherent variation of two muscles from each carcass on meat quality characteristics at various stages of chronological age and 3) the influence of level of fat within each muscle from animals differing in chronological age on the various meat quality factors.

REVIEW OF LITERATURE

Panel evaluation of organoleptic qualities of meat.

Although consumer acceptance is the ultimate goal of new products from meat research, consumer panels are not always feasible. Consumer panels are generally employed to predict future market performance of meat and meat products on the basis of past and present consumer preferences. Consequently, most palatability studies are designed to use small test panels. Taste panels determine differences in treatments and the magnitude of these differences (Weir, 1960). The factors most commonly evaluated in meat by a test panel are tenderness, juiciness, flavor and odor intensity. This poses problems such as the selection and training of panel members, method of presentation (uniform sample size and sample temperature) and method of scoring. The time and conditions of sample storage and use of sufficient samples within a definable population to make the results valid and meaningful are important to the study of palatability characteristics (Blumer, 1963).

In studies at the University of California, Simone et al. (1959) and Dunsing (1959) conducted a laboratory taste panel concurrent with a household panel to evaluate visual and eating preferences. They used 16 Hereford steers from two age groups, 18 and 30 months. Simone et al. (1959) paired the carcasses by comparable quality and appearance. When tenderness was scored by the laboratory panel, highly significant grade and age effects were found. The younger animals were more tender, but juiciness and flavor were not significantly affected by the age difference between the two groups. Dunsing (1959) used steaks from these same animals and paired them by either different carcass age or carcass age and grade. The over-all visual preferences differed by wholesale cuts and grades, but the over-all eating preferences were consistently in favor of the younger animals.

Evaluations for the specific eating factors of taste, tenderness and juiciness were similar to the over-all eating scores. The consumer panel indicated a much more pronounced preference for the tenderness factor than the other two factors. The laboratory panel was in agreement with the consumer panel on scoring the younger carcasses more tender. For the other two factors (juiciness and flavor) the laboratory panel differed from the consumer panel by scoring in favor of the older rather than the younger carcasses. The authors suggested that the two panels differed considerably in the relative importance which they attached to a specific organoleptic factor in terms of providing eating satisfaction.

Panel tenderness measurements.

Panel tenderness may be measured as a single value using a hedonic scale (Peryam and Pilgrim, 1957), chew count method (Lowe, 1949) or rate the meat for tenderness components (Cover et al. 1962abc). It is apparent that several properties may be involved in the sensation of tenderness. These are initial resistance as tenderness of the cooked meat tissue (ease with which the teeth sink into the meat when chewing begins), mastication of a bite of meat (softness, crumbliness or friability of the muscle fibers) or the nature of the residue (connective tissue). To evaluate palatability characteristics it is very important that the sample be chewed thoroughly.

Mechanical measurements of tenderness.

Objective methods have been developed to measure tenderness. The methods can be divided into shear devices, penetration devices and food grinder methods. The shear method generally used for tenderness studies is the Warner-Bratzler shearing device. When reviewing shear data attention must be paid to the thickness of the piece of meat, degree of doneness of the cooked sample and temperature of the sample at shearing. Sampling so that a representative sample is sheared (avoid large connective tissue and fat deposits), size and shape of the core, alignment of muscle fibers and speed of shearing may be sources of error in the Warner-Bratzler shear data (Bratzler, 1949).

Comparisons of tenderness as measured by panel or shear machine.

There has been much discussion as to the measurement of comparable qualities described as tenderness by a taste panel compared with the Warner-Bratzler shear. It is suggested that the tenderness sensation available to the taste panel from tooth and jaw pressure (which should correlate closely with mechanical shears) may be modified by additional and contradictory sensations from tongue and cheek in certain muscles (Cover and Smith, 1956). Cover et al. (1962d) made an extensive study of tenderness components and shear force. They found that cooked meat with a large amount of unchanged collagen in its connective tissue would be called tough by a panel, yet shear force does not appear to measure it accurately. Meat cooked rare is soft and juicy and may be swallowed with little chewing, even when the muscle fibers adhere tightly and do not fragment easily. This kind of "tenderness" is not related to shear force. In well-done meat the ease of fragmentation of muscle fibers and adhesion between muscle fibers is related to shears. Shear force seems to follow rather well the change in hardness (toughening) in meat brought about by cooking from rare to well-done.

Deatherage and Garnatz (1952) warned against the synonymous use of the terms shear strength (as determined by the Warner-Bratzler machine) and tenderness of meat. They compared 32 pairs of matched shortloins, one side aged by Tenderay process and the other side used as a control. The relationship between shear values and panel scores was not as close as would be desirable. The authors felt that "shear strength measures a variable which is related to tenderness of meat but from the correlation coefficient of 0.17, this is not the dominant variable". Using shortloin steaks from 536 carcasses, Carpenter et al. (1958) reported highly significant correlation between panel and shear force tenderness values.

Blackmon (1960) using 16 Hereford females of four age groups and two aging periods reported a significant correlation (-.84) between shear and taste panels. Kropf and Graf (1959) using a total of 334 beef carcasses of different grades, sex classes and weights reported that sensory tenderness versus mechanical shear value showed a highly significant correlation of -.78. They felt that shear values were more sensitive determinants of meat tenderness than the sensory values. A negative correlation is reported because as meat becomes more tender a higher score is indicated by taste panels but less pounds of force is required for shearing.

Cover and Smith (1956) used 38 steers and found a highly significant relationship between tenderness score and shear force which indicated that shear force value accounted for between 50 and 80 percent of the variation in tenderness score. However, in other studies Cover and Hostetler (1960) reported that shear and tenderness scores "were not as close as desirable and that shear force values appeared to be less than perfect as a measure of total tenderness of meat from all cuts".

The literature cites many correlations of shear and taste panel. However, the correlations above are reported since they too take into consideration the varying ages of the animals. It seems that shear strength as measured by the Warner-Bratzler shearing machine and tenderness as measured by the taste panel both evaluate some property of meat in a fairly reproducible manner. Furthermore, these properties change with post-mortem handling of the meat and each may be based fundamentally on more than one variable (Deatherage and Garnatz, 1952). Although shear force and taste panels may not be an absolute measurement of tenderness of a piece of meat, they both have their place as research guides to the eating quality known as tenderness.

Effect of age of the animal on tenderness ratings.

It has been generally accepted that meat from old animals is not as tender as meat from young animals, but that meat from the older animals is more juicy and flavorful than their younger counterparts. Palatability studies using the age of the animals as the influencing variable are determined by two methods. The exact chronological age is used when known. Where the age is unknown the maturity of the animals is estimated by the characteristics of meat and bone. Each system has its advantages, the former for noting palatability differences of beef due to exact chronological age. In the latter case, the maturity characteristics of the meat are used to separate beef according to the stage of maturity by visual appraisal as used in the federal grading system (Blumer, 1963).

In studies of maturity or age the interrelated factors (genetic, environmental, chemical, microbiological, histological, processing and method of evaluation) must be considered. The results indicated by such studies are very often more influenced by these factors than the differences in ages or age spans being studied.

Effect of marbling in the muscle on tenderness ratings.

Like maturity, marbling is a dominating factor for the visual appraisal of meat. Marbling is the term used to indicate intramuscular fat. There are 12 marbling scores in the present Federal Grade Standards varying from an extremely abundant to a devoid amount of intramuscular fat. The term in its strictest sense refers only to that fat which appears visible to the unaided eye on cut meat surfaces. It also includes microscopic deposits within various cells of muscles, some of which are not fat cells (Blumer, 1963).

According to Cover and Hostetler (1960), "Marbling has been regarded as an indicator of tenderness because the fat deposited in the cells was supposed to distend them and make them more tender". It was theorized that the fat spread apart the strands of connective tissue between the muscle fibers and between the muscle bundles, making the meat more tender. In addition it is possible that the lubricating qualities of fat may affect the ease with which the meat is masticated and/or swallowed (Blumer, 1963).

Fat content of beef is measured for research purposes by physical separation (Hankins and Howe, 1946), by visual estimation of marbling (generally at the 12th rib) and by determination of the percent ether extract (A.O.A.C., 1945).

Cover et al. (1956) correlated the various methods of measuring fatness. The correlation between the estimated fat in the carcass versus the estimated marbling was significant (r = .78). The correlation between estimated marbling and ether extract is lower (r = .60) and those between estimated fat in the carcass and ether extract is lowest of all (r = .52).

Studies of animal maturity and marbling and relationship to tenderness ratings.

Foster (1928) compared the beef from a mature steer of nine years with that of an immature steer that was one year old. He noted that the marbling from the mature carcass was much superior to the immature carcass. A panel rated roasts from the 9-10-11th rib about equal in tenderness from the two animals. However, the mature carcass was rated superior in aroma, flavor and juiciness. Hiner and Hankins (1950) using the Warner-Bratzler shear found differences in the meat between young and more mature carcasses. Fifty-two animals of the ages, 5-1/2 year old cows, 3 year old heifers, 16 month old steers, 7 month old calves and veal calves of 2-1/2 months were sampled. The difference between veal and cows was highly significant, whereas that between veal and beef from the 7 month old steer calves was non-significant. Correlation coefficients showed no close relationship between different samples within the same age groups with respect to tenderness. As the age of the animal increased, tenderness decreased for each of the nine samples taken from each animal.

The effect of marbling and maturity on tenderness of beef carcasses was studied by Walter et al. (1963). Carcasses from 72 animals were divided into three maturity groups (A, B and F) and six marbling levels (ranging from moderately abundant to practically devoid). Panel tenderness decreased with advancing age, but the difference between the two younger maturity groups was not significant. Evaluating tenderness by the two components of initial tenderness and residual tenderness substantiated the above over-all panel tenderness score. Age had a highly significant effect on tenderness in this study but the effects of marbling were non-significant.

Alsmeyer et al. (1959) combined two studies to find the relative significance of age, marbling and carcass grade as associated with an age span of 5 to 87 months. Marbling influenced shear tenderness more strongly than did age at slaughter. Age at time of slaughter accounted for only 8.1 percent of the variability in tenderness. In the second experiment, they combined some animals from the first study to give a total of 502 carcasses with an age span of 5 to 30 months. A highly significant correlation coefficient was obtained between tenderness and age at slaughter without respect to degree of marbling.

Helser (1930) used 8 month old calves, 20 month old yearlings and 32 month old animals to test for tenderness using a meat testing dynamometer. The samples from the calves required more pounds to shear than did the samples from older animals. The explanation given by Helser is that the lean meat from the older steers had more intramuscular fat; showed more marbling and lesser number of muscle fibers per unit area. "The resistance to the fat would not be so great as that of the muscle fibers" (Helser, 1930).

The effect of degree of finish on beef carcasses was investigated by Nelson _et al_. (1930). They used the same 8, 20 and 32 month old animals of Helser (1930). Half of each age group was unfinished (feeders) at the time of slaughter, the other half was fattened before slaughter. Results of over-all scoring indicated that in almost every case the fattened carcasses scored higher in palatability than the unfinished ones. Tenderness was not greatly influenced by age in this study. Jacobson and Fenton (1956a) studied the level of nutrition and the age of the animal on the quality of beef from dairy breeds of cattle. Duplicate animals of each level of nutrition (low, medium and high) for each age (32, 48, 64 and 80 weeks) were used. In general, tenderness scores tended to favor the 48 week old animals and the score for palatability tended to decrease after the 48 week age.

Blackmon (1960) and Tuma (1962) found that steaks from calves required as great a shear force as more mature animals. Both studies used Hereford females of 6, 18, 42 and 90 months. One side was aged 48 hours while the other side was aged 14 days. The pounds of shear force for the _longissimus dorsi_ muscle steaks for the 6 month group were as great as that for the 42 and 90 month groups. The 18 month group was the most tender. In both studies, the taste panel scored steaks less tender with increasing animal age. Tuma (1962) noted that the marbling x age interaction for shear values indicated that all age groups were not related to marbling in the same manner. Aging the steak 14 days seemed to have greater influence on tenderness of steak from younger animals than from the older animal groups.

Studies by Cover _et al_. (1958) showed that marbling accounted for only 11 percent of the variability in tenderness. Wellington and Stouffer (1959) observed that intracellular fat expressed as ether extract and the relationship with tenderness was non-significant (r = .08) while panel tenderness scores gave a correlation of 0.26, significant at the 5 percent level. Using the higher correlation of panel scores, marbling accounted for about 7 percent variability in tenderness. Cover _et al_. (1956) mentioned that percent ether extract measured not only fat as seen as marbling but also fat deposits along seams of heavy connective tissue. This would not be called marbling by visual appraisal.

Variation of tenderness as associated with different muscles.

Lowe and Kastelic (1961) on the other hand found some relationship to exist between tenderness of muscle and fat content. However, some muscles did not conform to the general pattern. Hankins and Ellis (1939) found no significant correlation between the fat content and the tenderness of cooked _longissimus dorsi_ muscle.

It is commonly known that different muscles from a given animal vary in tenderness and that the tenderness of a muscle from one animal may differ from the same muscle in another animal. Ramsbottom _et al_. (1945) studied the comparative tenderness of 25 representative muscles from three beef carcasses. Tenderness as determined by shear readings on different parts of the same muscle occurring in different wholesale cuts indicated variation in tenderness within the muscles of the back and loin. Harrison et al. (1949) paired muscles of psoas major, longissimus dorsi, semitendinosus and semimembranosus for their physical and organoleptic study. Four animals of different ages were used: two yearling steers, one slightly older than the other; a third steer, about 14 months of age; and an 8 year old dairy cow. The most tender roasts came from muscles and from animals having the least connective tissue. However, variations of the palatability factors were found among the muscles, among the carcass grades and among the animals within a carcass grade.

Histological measurements.

Ramsbottom et al. (1945) felt that the difference in the amount of connective tissue associated with intramuscular fat may explain why no relationship was found between the amount of fat within a muscle and the shear value of the muscle. Wilson et al. (1954) noted no consistent increase or decrease in collagen associated with grade or the amount of intramuscular fat. Mitchell et al. (1928) and Hiner et al. (1955) reported that in muscles where fatty deposits were evident, collagenous fibers formed a loose network between muscle bundles and in those with less fat, the connective tissue was bunched. Henrickson et al. (1963) suggested that when using the Warner-Bratzler shear machine for tenderness determination, less actual muscle fibers and connective tissue would be present in a 1-inch core when fat is a component then when fat is not a large component.

Muscle fibers.

As the beef animal matures, histological changes occur within the meat tissue that affect the tenderness of the meat. A young animal has muscles made up of small fibers. It has been shown by many workers that as the animal matures the fiber diameter increases. Tuma et al. (1962a) using animals of five age groups (6, 18, 24, 42 and 90 months) reported that a gradual increase in fiber diameter with increased animal age was noted for the longissimus dorsi muscle. The fiber diameter in the semitendinosus muscle increased at 6, 18 and 24 months, then leveled off.

Lehmann (1907) reported that the smaller the muscle fibers the more tender the meat but Brady (1937) found a non-significant correlation between fiber diameter and shear. Nine samples of muscles from each of 52 beef animals were used by Hiner et al. (1953). The ages varied from 10 weeks to 9 years. Analysis of fiber diameters indicated that the greatest change in size occurred between 8 and 14 months of age and that there was only a small difference in fiber size between veal calves and 500 pound steers. Hiner et al. (1953) reported that as fiber diameter increased, resistance to shear increased. Analysis of variance showed that fiber diameter and shear tenderness of the animals and samples was highly significant but the interaction of the two was also significant. The working muscles had generally higher correlation coefficients than those less worked. Tenderness and fiber diameter in mature animals were found to be more closely associated than in the younger more immature cattle (cows, $r = .77$ and veal calves, $r = .50$).

Tuma et al. (1962a) noted that the larger the muscle fiber, the lower (less desirable) the taste panel tenderness score. When age effect was removed, essentially no relationship was noted between panel score and fiber diameter; therefore, they concluded that fiber diameter was a poor indicator of tenderness.

Connective tissue.

Lehmann (1907) believed that the connective tissue fiber, rather than muscle fibers is the cause for a greater portion of the toughness of meat. Mitchell et al. (1928) stated that age does not seem to have a great effect on connective tissue content in muscle or a consistent effect among the different muscles of the carcass. Gersh and Catchpole (1949) and Porter (1951) suggested that the absolute amount of connective tissue remains fairly constant throughout life, and small connective fibers coaleasce into larger, stronger fibers with age. Therefore, a sample from a mature animal, possessing larger connective tissue fibers, will contain more intracellular protein than a sample of veal of similar size.

In the study by Wilson et al. (1954), veal samples had a significantly greater amount of collagen and elastin than cow or steer samples, but no significant difference was observed in the last two. He reasoned that since the collagen fibers are surrounded by reticulum, it may also be determined chemically as collagen in most cases. Since the fibers of a young animal are smaller, a greater amount of reticulum would be associated with young animals and a higher collagen value would thus be obtained.

Mitchell et al. (1928) reported that the longissimus dorsi had the lowest collagen content, with the tenderloin slightly higher and the muscles from the round, porterhouse and sirloin next in order.

The percent of elastin in connective tissue is a small fraction of the percentage of collagen found in connective tissue. The chuck and round contained over three times the elastin as found in the tenderloin, sirloin and ribeye. The distribution of elastic fibers in connective tissue are scattered in appearance in more tender samples and bunched into definite areas in less tender round muscles. Muscles used for movement and/or work, have large bunched elastic fibers, but in the little strained muscles, the elastic fibers are narrow and dispersed (Hiner et al. 1955).

Hiner et al. (1955) indicated that the size of the elastic fibers in veal and calves is noticeably smaller than in mature heifers and cows. He concluded that as the animal matures, the size of elastic fibers increases, and suggested this as a factor in the increase of shearing resistance associated with maturity. In samples with a higher resistance to shear, the elastic fibers are very abundant.

Ramsbottom et al. (1945) using 25 muscles from each of three carcasses showed that muscles with small amounts of connective tissue had low shear readings while those with large connective tissue had higher shears. The relative amounts of collagenous and elastic tissue and shear readings had a definite correlation in the study by Ramsbottom et al. (1945).

The interrelationships of the micro-components of fat, fiber diameter, collagen and elastin appear to be contributing factors for the tenderness or toughness of meat. The size, amount and character of these micro-structures have been studied individually, but not adequately as interrelated factors.

Panel juiciness measurements.

Taste panels generally are asked to score juiciness and flavor when rating meat for palatability studies. Juiciness, like tenderness, is not truly a single taste sensation. The first sensation of juiciness may be due to moistness or amount of fluid in the cooked meat, while the sensation of sustained juiciness probably depends upon stimulation of salivary action of fat and other physiological effects (Doty, 1959). Therefore, juiciness and tenderness may be related; the more tender the meat the more quickly the juices are released by chewing and the more juicy the meat appears.

Since juiciness refers to the liquid detectable during chewing of a bite of meat, evaluation of juiciness can be made both qualitatively and quantitatively (Blumer, 1963). The juiciness as measured by both ways tend to increase slightly as the animals become older.

Barbella et al. (1939) based findings on 728 heifer and steer cattle of various breeds. They ranged in age from 8 to 42 months. Quantity of juice of beef ribs increased quite rapidly with increase in fatness to 22.5 percent fat and more slowly to 42.5 percent, after which there was no apparent effect. There was a slight tendency for the meat from the 11 month group to be more juicy than the other groups.

When attempting to separate juiciness scores from tenderness, Cover (1959) found that softness is the only one of the three tenderness components which is positively correlated with juiciness.

Panel flavor measurements.

Studies on flavor have necessarily been limited to subjective panel ratings as instruments do not record taste sensations although they are used for identification of flavor components.

The flavor compounds of meat are present both in the liquid and solid portion of meat tissue. Meat flavor intensity and aroma are very difficult to evaluate and describe. It is hard to separate these two characteristics since many of the flavor properties are really the result of aroma sensations (Blumer, 1963). It takes training to separate and evaluate flavor if another of the organoleptic qualities is unacceptable. Taste is composed of four components (bitter, sour, salt and sweet). The outstanding presence of one may affect or modify the other three. Kurtz (1959) summed up flavor by defining it as "a complex of sensations resulting from the stimulation of the senses of odor, taste, feel and sometimes vision and audition".

Studies of variables influencing juiciness and flavor ratings.

Blackmon (1960) reported that juiciness and flavor were not influenced appreciably by the animal age span of 6, 18, 42 and 90 months. Aging the meat for 14 days seemed to improve the scores for the first two age groups, but no observable difference was encountered for flavor between the 42 and 90 month groups. A decrease in juiciness was observed for the older group. Tuma et al. (1962b) indicated that the effect of aging 14 days differed with animal age (18, 42 and 90 months), marbling level and method of measuring tenderness (taste panel or Warner-Bratzler shear). Taste panel flavor and juiciness scores did not appear to be related to animal age, marbling level or aging 14 days.

Jacobson and Fenton (1956a) reported tenderness and juiciness values of three muscles (longissimus dorsi, psoas major and semimembranosus with adductor) from 24 Holstein heifers. A consistent and highly significant decrease in juiciness was noticed for all three muscles with age. Tenderness scores decreased with age particularly in the semimembranosus muscle. Differences in tenderness were not found in the "chew" values with increased age.

The effect of cooking.

The initial acceptance or rejection for a piece of meat is in the raw state, but for the real test of eating quality, it is in the cooked state. Cooking is a major factor that affects the acceptability of the product. Cooking develops flavor and tenderizes. "The changes brought about by cooking may be slight or great, depending on how well done the meat is cooked. The characteristic changes produced by cooking consist of change in color, loss in weight, contraction in volume, changes in fatty tissue, changes in structural proteins or connective tissue, changes in muscle fibers and change in flavor. The loss of fat and fluids accounts for the greater portion of the loss in weight during cooking" (Lowe, 1955).

Tenderness and flavor are greatly dependent on cooking method, temperature and length of cooking, size of piece of meat and the nature of the connective tissue. The time factor seems to be more important for collagen softening while the maximum temperature appears to be more important for muscle fiber toughening (Weir, 1960). Perhaps the most important factor influencing the juiciness of cooked meat is the cooking procedure. In general, those cooking procedures that result in the greatest retention of fluids and fat will yield the juiciest meat. For this reason juiciness usually varies inversely with cooking losses.

The effects of specific cooking temperatures over time and tenderness, cutability and shear press value of beef were determined by

Tuomy et al. (1963). The cooking temperatures investigated were 140, 160, 180, 190, 200 and 210°F over a seven hour period. The initial effect of heat was a toughening which increased as the temperature increased. When the meat was held below 180°F, the tenderness of the cooked meat depended on temperature, with time having little or no effect. Above 180°F the meat became tender at a rate and to a degree dependent upon both time and temperature.

Lowe and Kastelic (1961) studied the difference in palatability and composition of meat from steer carcasses differing in age and grade. Cuts from one side were roasted or braised to 158°F and the other side to 194°F. The age of the animal did not effect the cooking weight losses, the shear values or juiciness scores. The roasts cooked to 158°F were scored higher in tenderness by the taste panel than those cooked to 194°F, but the shear force did not indicate this difference in tenderness. The majority of the cuts cooked to 194°F were less juicy and less desirable in flavor.

Ramsbottom et al. (1945) found that shear readings on cooked meat were positively correlated with shear readings on the raw meat. Ramsbottom et al. (1945) stated that although connective tissue and fatty tissue are made more tender by cooking, the decrease in tenderness noted may be associated with coagulation and denaturation of muscle proteins, coupled with shrinkage and hardening of the muscle fibers.

In the study by Walter et al. (1963) using three maturity groups of carcasses, a significant effect was noted for age, cooking methods and the positions at which the cores were removed for shear. Tenderness decreased a great deal with advancing age but no pattern of the effects of marbling on tenderness were noted. Broiled steaks were significantly more tender than deep fat fried steaks as measured by the Warner-Bratzler shear.

Summary of variables influencing the measurements of tenderness, flavor and juiciness.

The seemingly contradictory results of these investigations reflect the fact that the physical and chemical structure of the product we call beef is very heterogenic. Variations in biological materials cannot be eliminated, even when standardized techniques are used. When so many factors affect the organoleptic ratings of the muscle, and each factor to unequal degrees, it is easily understood that variation in palatability characteristics may occur in animals of the same genetic, environmental and pre- and post-mortem handling. Table I is designed to show that the literature reviewed differs in procedure and technique and therefore, over-all comparisons and conclusions cannot be made.

TABLE I

VARIATION IN FACTORS AFFECTING SOME ORGANOLEPTIC STUDIES

Author	Year	No. Ani.	Ages	Aging	Cooking Method	Internal Temper.	Muscle or Cut
Foster	1928	2	1 & 9 yr	10 da	roasted	140^{o}F	9-10-11 rib roasts
Helser	1930		8, 20 & 32 mo	5 da			12th rib steak (LD)
Nelson *et al.*	1930		8, 20 & 32 mo	9-69 da	roasted	134.6^{o}F	9-10-11 rib roasts
Barbella *et al.*	1939	728	8-42 mo		roasted	rare	9-10-11 rib roasts
Ramsbottom *et al.*	1945	3	500#	3-4 da	deep-fat	170^{o}F	25 muscle cuts
Harrison *et al.*	1949	4	(2) yearlings, 14 mo & 8 yr	1, 2, 5, 10, 20 & 30 da			Pm, LD, St & Sm roasts
Hiner & Hankins	1950	52	2½, 7, 16 mo 5½ & 3 yr	12-15 da	roasted	140^{o}F	9 cuts
Deatherage & Garnatz	1952	32	commercially slaughtered	Tenderay & control 5 da	broiled		shortloin steaks
Jacobson & Fenton	1956a	24	32, 48, 64 & 80 wk	7 da	roasted	156^{o}F	LD, Pm, Sm roasts
Alsmeyer *et al.*	1959						
Study 1.		281	5-87 mo	48 hr	broiled	medium	shortloin steaks
Study 2.		502	5-30 mo	48 hr	broiled	medium	shortloin steaks
Kropf & Graf	1959	334	400, 600 & 800#	24-48 hr	cores in 158^{o}F water bath for 3 min.		loin strip steaks

TABLE I (Continued)

Author	Year	No. Ani.	Ages	Aging	Cooking Method	Internal Temper.	Muscle or Cut
Dunsing	1959	16	18 & 30 mo	8 da	consumer cooked		shortloin & sirloin steaks
Simone	1959	16	18 & 30 mo	8 da	roasted	155°F 170°F	6-7-8 & 9-10-11 rib roasts top round roasts
Wellington & Stouffer	1959	121	12-24 mo	5-8 da	deep-fat	145°F	ribeye steaks
Blackmon	1960	16	6, 18, 42 & 90 mo	lt: 2 da rt: 14 da	broiled	150°F	rib (LD) steaks
Cover & Hostetler	1960	91	13-16 mo	7 da	broiled braised	142-175°F 185-212°F	loin (LD) & bottom round (Bf)
Lowe & Kastelic	1961	8	6-42	7-10 da	roasted or braised	lt: 158°F rt: 194°F	rib, loin, tender-loin & round roasts
Tuma	1962	56	6, 18, 42 & 90 mo	lt: 2 da rt: 14 da	broiled	150°F	rib (LD) steaks
Tuma *et al.*	1962b	24	18, 42 & 90 mo	lt: 2 da rt: 14 da	broiled	150°F	rib (LD) steaks
Walter *et al.*	1963	72	A, B & F maturity	7-9 da	broiled & deep-fat	60°C	9-12th rib

PROCEDURE

Materials.

Eighty-five Hereford steers and females from the Oklahoma Agricultural Experiment Station herd were used for this study. All animals were of similar genetic and management background, and were confined to a similar ration where feasible. The 18, 42 and 90 month animals were pastured on native Oklahoma grasses and supplemented ad libitum with ground ear corn, chopped alfalfa hay, cottonseed hulls, cottonseed meal, bran, whole oats and molasses. The 6 month old animals were creep fed a ration consisting of predominantly ground milo while on nurse cows for the complete term prior to slaughter. Each live animal was selected in an attempt to provide a carcass with one of the designated marbling levels of slight amount or slightly abundant. The age criteria for selection was within 10 percent of the ages of 6, 18, 42 and 90 months.

Methods.

Slaughtering, cutting and freezing.

Slaughtering and cutting were done in accordance with methods described in Proceeding of 4th (Deans, 1951) and 6th (Wellington, 1953) Reciprocal Meat Conferences. Immediately after slaughter and dressing, the carcasses were placed in a 34-36^{o}F cooler for a 2-day chilling period. The carcasses were visually appraised and graded by an Official Meat Grader of the United States Department of Agriculture.

The longissimus dorsi (shortloin) and semitendinosus muscles from both sides were studied in detail. The left sides were sampled after 2 days post-mortem (chilled), while the muscles from the right sides were left intact in the wholesale cut for 14 days post-mortem (aging) at 34-36°F then sampled. Sampling locations were identical for each carcass (Figure 1). The boned and trimmed steaks from the two muscles were wrapped individually and quick frozen in an air blast freezer at -20°F and then held at -10°F until time of evaluation.

Figure 1

Sampling Locations for Each Muscle

1st Lumbar	Posterior	Longissimus dorsi
		1. 2" steak - shear
1. 2. 3.	longissimus dorsi	2. 1" steak - taste panel
		3. 2" steak - chemical analysis
	Posterior	**Semitendinosus**
		1. 2" steak - shear
1. 2. 3.	semitendinosus	2. 1" steak - taste panel
		3. 2" steak - chemical analysis

Cooking.

The 2-inch steaks used for shear evaluation were removed from the -10°F freezer and thawed in a 40°F cooler for 12 to 14 hours. An open-faced gas griddle-broiler was used to broil the steaks to an internal temperature of 150°F. After broiling was complete, the temperature of each steak was allowed to equalize before removing cores for shear determination.

Shearing.

Shear values were determined by use of 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. Three cores (lateral, medial and dorsal) were removed from the longissimus dorsi muscle steak. Three 1-inch cores were also removed from semitendinosus steaks but in a circular pattern. Three shears were made on each core, giving a total of nine values per steak. The average of these nine values was used in the statistical treatment of the data.

Organoleptic evaluation.

Steaks for sensory evaluation were 1-inch thick and broiled in the same manner as those for shear determinations. "Bite-size" portions (3/4 inch cores) were removed from each steak for the sensory analysis. The taste panel used throughout this work consisted of meat laboratory personnel. Although the panel was not trained primarily for this study, the members were considered competent to evaluate organoleptic properties of the meat. Panel members were instructed to score the meat for each component, tenderness, juiciness and flavor on an 8-point hedonic scale (Figure 2), with 8 being the highest rating. The sensory values used in the statistical treatment of the data are an average of the panel scores for each of the organoleptic components.

Chemical analysis.

Muscle samples for proximate analysis were taken from the -10°F freezer and the outer edges trimmed free of fat and connective tissue. Each sample was blended to a paste consistency. Duplicate aliquots were used for percent moisture and percent ether extract analysis (A.O.A.C., 1945).

FIGURE 2

HEDONIC SCALE FOR TASTE PANEL TO SCORE
QUALITY FACTORS OF INDIVIDUAL STEAK

	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	

COMMENTS:

Analysis of data.

In appraising this study there are several points that should be mentioned. Even though an effort was made to select calves at birth with superior conformation, and encourage them to consume grain from a self-feeder while taking milk from nurse cows, they failed to deposit enough fat in the longissimus dorsi muscle to be scored slightly abundant. Cattle from the three older groups, 18, 42 and 90 months, were fed as near alike as possible, although it is recognized that the feed requirements are different for cattle which vary this much in age. While it was necessary to use steers and heifers for the 6 and 18 month old groups, only females were used for the 42 and 90 month age groups. The animals were selected from the feedlot herd when they were considered to have the desired amount of marbling by visual appraisal of the live animals. The genetic potential of the animals caused the "poor doers" to be used for the low marbling level while the "early maturing, easily fattened" animals were used in the high level group. No attempt was made to access the influence of these factors on the quality of the carcass or tissues (Henrickson et al., 1963).

From the population of these 85 animals slaughtered, 40 carcasses were combined to fit the desired fat levels for each age group (Figure 3). The two muscles used were from sides that had been chilled 2 days. The wide age range of 6 to 90 months was used in an attempt to produce beef showing various states of physiological maturity and development.

Figure 3

Statistical Design for Each Age Group

Selected Traits				
Age (Months)	6	18	42	90
Level of Fat (Average)	High		Low	
Muscle[1]	LD	ST	LD	ST
Number in Group	5	5	5	5
Total Animals (40)				

[1]LD - Longissimus dorsi
ST - Semitendinosus

RESULTS AND DISCUSSION

Shear.

Shear values reported for the 80 individual steaks in this study ranged from 7.2 to 38.7 pounds of shear force. The general response pattern for Warner-Bratzler shear was practically the same for each age group regardless of muscle and level of fat (Figure 4). The only deviation to this general pattern occurred with the high level *semitendinosus* muscle. In a study by Lowe and Kastelic (1961) it was also noted that the tenderness of the *semitendinosus* did not follow the same relationship of other muscles with regard to fat content. The analysis of variance showed that the effect of animal age was highly significant ($P < .01$) (Table II). At 6 months of age the shear resistance average was 17.0 pounds (Table III). Less pounds of force was needed to shear the steaks from the 18 month old animals than the other three age groups (13.9 pounds). Meat from this age level was the most tender group studied. Blackmon (1960) and Tuma (1962) using animals of this same management, genetic background and age span also reported the 18 month group to be the most tender. In addition Tuma *et al*. (1962b) suggested that animal age may be more critical with regard to tenderness at a point between 18 and 42 months. Simone *et al*. (1959) and Dunsing (1959) indicated the greatest increase in tenderness may fall between 18 and 30 months of age. Alsmeyer *et al*. (1959) using 502 carcasses reported that tenderness increased from 5 to 30 months

FIGURE 4

SHEAR VALUES AS INFLUENCED BY ANIMAL AGE, MUSCLE AND FAT LEVEL

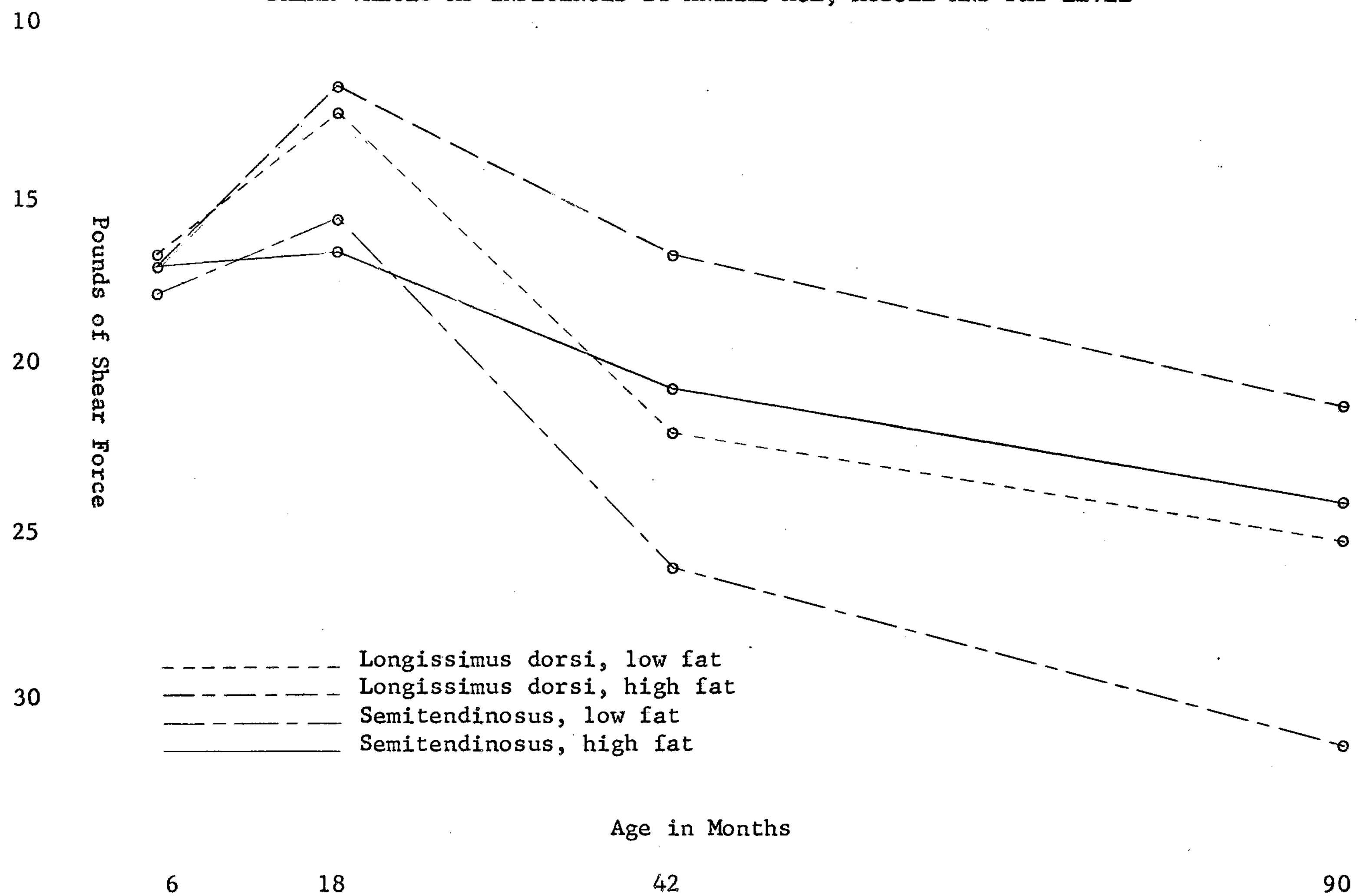


TABLE II

ANALYSIS OF VARIANCE FOR SHEAR

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	248.54	9.23	.01
Fat Level	1	38.78	1.44	NS
Muscle	1	52.49	3.66	NS
Age x Muscle	3	63.72	4.45	.05
Age x Fat Level	3	66.64	2.47	NS
Muscle x Fat Level	1	18.57	1.30	NS
Age x Muscle x Fat Level	3	274.45	19.15	.01
Animal in Age x Fat Level	32	26.94		
Animal x Muscle in Age x Fat	32	14.33		

[1] NS - Not significant at 5 percent level of probability.
.05 - $P < .05$.
.01 - $P < .01$.

of age. Blackmon (1960) suggested that the increased tenderness in the 18 month group was associated with higher degree of marbling but Tuma et al. (1962) using only two marbling levels (slightly abundant as compared to slight amount) indicated that marbling did not enhance the tenderness of the steaks from the 18 month old animals.

The greatest decrease in tenderness occurred by the time the animals reached 42 months, the 42 month group required an average of 7.4 pounds more shear force (21.3 pounds) than the 18 month steaks. As the animals approached the age of 90 months, another decrease in shear value was noted with the 90 month animals having the least tender steaks (25.4 pounds) (Table III).

An age x muscle interaction was significant ($P < .05$). Interaction measures the failure of the tenderness of each muscle to be the same at each age level or the failure of tenderness of the four age levels to be the same for each muscle. The longissimus dorsi and semitendinosus for the four age groups averaged over both levels of fat showed the same trend as the age means (Table IV). The steaks from the 18 month old cattle were the most tender for both muscles (12.0 pounds for longissimus dorsi and 15.9 pounds of shear force for the semitendinosus). The effect of muscle was non-significant although the means for the longissimus dorsi were slightly more tender than the semitendinosus muscle steaks when not adjusted for age or fat level (17.8 and 21.0 pounds, respectively) (Table IV).

When individual muscles in each age groups were catagorized into low and high fat level according to the percentage ether extract, the age x fat level effect was non-significant at the 5 percent level. Looking at the age x fat level mean averaged over muscle, (Table V)

TABLE III

AGE MEANS FOR SHEAR[1]

Age in Months	6	18	42	90
Shear (lb.)	17.0	13.9	21.3	25.4

[1]Combined value for <u>longissimus</u> <u>dorsi</u> and <u>semitendinosus</u> muscles including both fat levels.

TABLE IV

AGE X MUSCLE MEANS FOR SHEAR[1,2]

Age in Months	6	18	42	90	Avg.
Longissimus dorsi	16.8	12.0	19.3	23.1	17.8
Semitendinosus	17.3	15.9	23.3	27.6	21.0

[1]Averaged over both levels of fat.
[2]Expressed in pounds, the greater the number of pounds the less tender the steak.

TABLE V

AGE X FAT LEVEL MEANS FOR SHEAR[1,2]

Age in Months	6	18	42	90	Avg.
Low Fat Level	17.2	13.9	23.9	28.2	20.8
High Fat Level	16.8	14.0	18.7	22.6	18.0

[1]Averaged over both muscles.
[2]Expressed in pounds, the greater the number of pounds the less tender the steak.

the fat level appears to have the greatest influence on tenderness at the 42 and 90 month ages where a difference of more than 5 pounds of shear force occurred in favor of the high fat level of each age group. Tuma et al. (1962b) noted that the more tender individual steaks from the 42 and 90 month animals were associated with the higher level of marbling. Ramsbottom et al. (1945) using 25 muscles from each of three carcasses reported no relationship between the amount of fat within the muscle and shear of raw or cooked muscle. They felt that the difference in the amount of connective tissue associated with intramuscular fat may explain the lack of relationship.

The three-way interaction of age x muscle x fat level is highly significant ($P < .01$). To interpret the main effects of this interaction, one must again look at a graph for each muscle at each fat level for the four age groups (Figure 4). The high fat level longissimus dorsi muscle is the most tender of the groups studied followed by the high level semitendinosus, the low fat level longissimus dorsi and the low fat level semitendinosus. A deviation occurs to this pattern between 18 and 42 months of age. The semitendinosus muscle with the high level of fat became more tender than the low level of fat longissimus dorsi muscle before the age of 42 months and continued to be more tender through the 90 month age. In the age span of 6 to 18 months an interaction occurred between fat levels with respect to both the longissimus dorsi and semitendinosus muscles.

This study did not attempt to find the reason for the differences occurring between age groups but to show that variation in tenderness does exist and to indicate the trend of this variation as the animal matures.

Although there are many pre- and post-mortem handling procedures that affect the tenderness ratings of the steaks, an effort was made to standardize these procedures as best suited for the group as a whole. Modification of any of these factors for each age group may have resulted in different conclusions.

It would appear from the literature reviewed that the muscle protein constituents and microscopic fat distribution may be the explanation for the varied ratings of shear tenderness. A young animal has muscles made up of small fibers which increase in size with maturity. Consequently, a 1-inch core from a young animal would contain more fibers than a 1-inch core from a mature animal. It was suggested by Beard (1924) that the inherent qualities of endomysium (thin network of collagenous tissue fibers separating individual muscle fibers) contributed more to toughness than the actual size of the muscle fibers. Greater shearing resistance in the meat from the younger animal may be accounted for by the greater amount of endomysial connective tissue present within the given volume.

The connective tissue is considered as a contributing factor to the toughness of meat. As the animal matures the elastin and collagen fibers coalesce into stronger fibers and tend to bunch showing greater resistance to shearing. This is especially true for "work" muscles as compared to muscles of support. Although collagen is softened by heat, the short cooking time needed to broil a steak may not have been adequate for sufficient hydrolysis.

Ramsbottom et al. (1945) pointed out that factors of cooking include coagulation and denaturation of proteins together with varying degrees of hardness and shrinkage of fibers. Grouped together these changes appear to exert a greater negative effect than the positive effect of partial collagen hydrolysis. Walter et al. (1963) found that cooking significantly increased the tenderness of steaks from younger animals, but did not affect the tenderness of steaks from more mature animals.

Between the animal ages of 6 and 42 months the steaks reached their maximum tenderness as determined by the Warner-Bratzler shear. The only maturity level studied between these two groups was 18 months. It is conceivable that at the age where maximum tenderness occurred, the micro-components of fat, muscle fibers and connective tissue fibers may have been at their most favorable relationship with one another for influencing tenderness as determined by Warner-Bratzler shear.

It is suggested that the shear values at 6 months would be influenced more by the endomysium and the number of fibers to be cut; while shear values of more mature animals would likely be influenced by the amount, kind and distribution of the connective tissue (Ramsbottom et al., 1945).

Panel tenderness.

When the panel scored the steaks for tenderness a different rating occurred than with the Warner-Bratzler shear. This supports the belief of many in the research field that shear and panels do not measure the same tenderness qualities of meat. A definite three-way interaction ($P < .01$) can be seen between 6 and 18 months of age where there is interaction between muscles, fat levels and muscle x fat (Figure 5).

When looking at the table of means for ages (Table VI) a decrease in tenderness is noted as age increased. The analysis of variance

FIGURE 5

PANEL TENDERNESS AS INFLUENCED BY ANIMAL AGE, MUSCLE AND LEVEL OF FAT

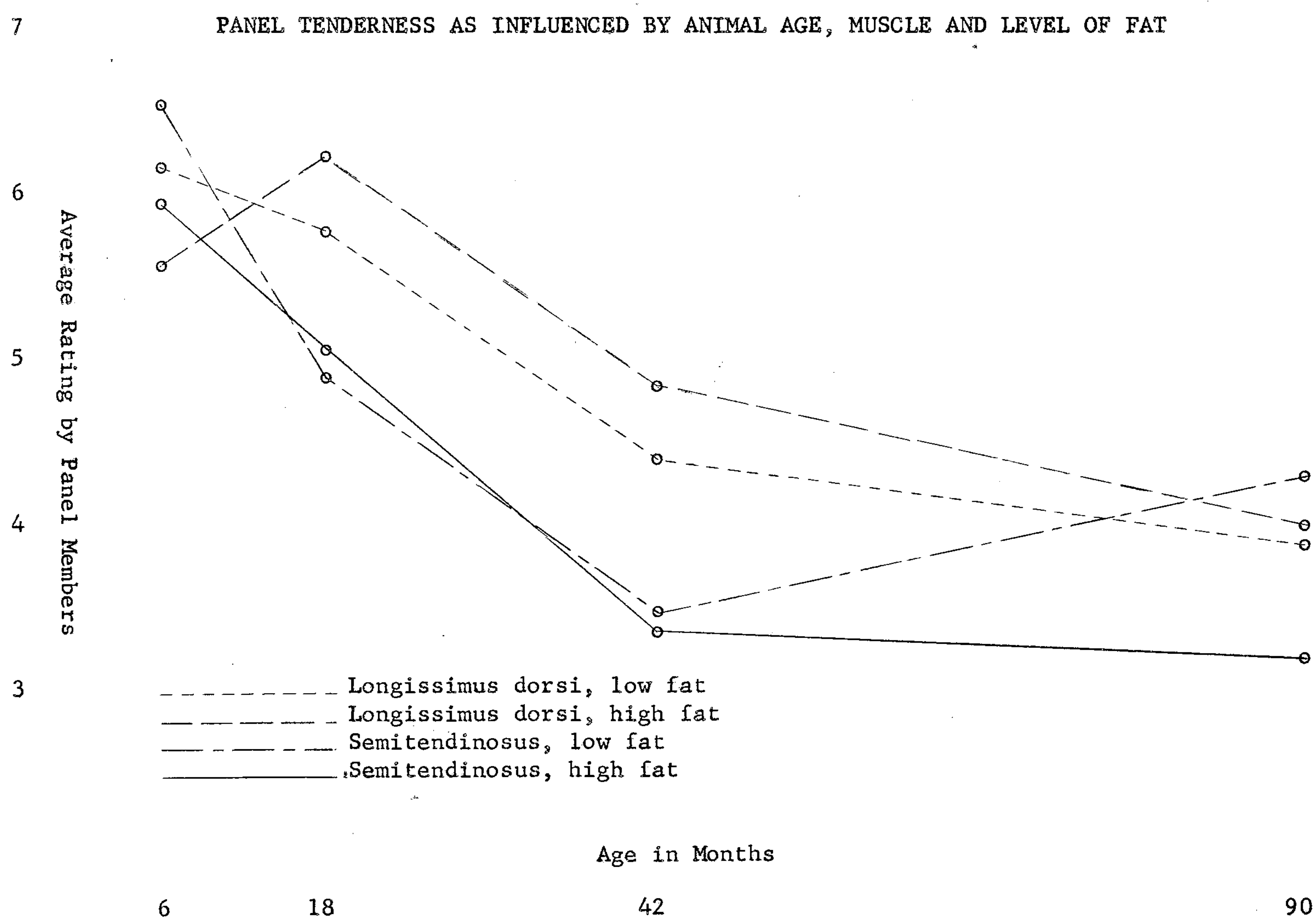


TABLE VI

AGE MEANS FOR PANEL TENDERNESS[1,2]

Age in Months	6	18	42	90
Panel Score	6.1	5.5	4.0	3.8

[1]Combined values for the _longissimus_ _dorsi_ and _semitendinosus_ muscles including both fat levels.
[2]Rated on hedonic scale with 8 being extremely tender and 1 equaling extremely tough.

TABLE VII

ANALYSIS OF VARIANCE FOR PANEL TENDERNESS

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	12.33	9.63	.01
Fat Level	1	.09	.07	NS
Muscle	1	1.37	1.34	NS
Age x Muscle	3	3.40	3.33	.05
Age x Fat Level	3	2.69	2.10	NS
Muscle x Fat Level	1	.42	.41	NS
Age x Muscle x Fat Level	3	12.22	11.97	.01
Animal in Age x Fat Level	32	1.28		
Animal x Muscle in Age x Fat	32	1.02		

[1] NS - Not significant at 5 percent level of probability.
.05 - $P < .05$.
.01 - $P < .01$.

indicated that the effect of age on tenderness was highly significant ($P < .01$) (Table VII). The panel scored all steaks from 6 month old animals an average of 6.1. This is a "moderately tender" rating. At 18 months, tenderness was scored 5.5. This decrease did not agree with the shear value which proclaimed the 18 month steaks to be the most tender of the age spans used. The 42 and 90 month steaks were approximately the same, as "slightly tough" (4.0 and 3.8, respectively).

The interaction of age and muscle was significant at the 5 percent level. The panel ratings for the steaks from the longissimus dorsi muscle indicated that 6 and 18 month age groups were comparable in tenderness (5.9 and 6.1, respectively) (Table VIII). A decrease of 1.5 points was noted for the span between 18 and 42 months. A slightly smaller decrease occurred between 42 and 90 months (4.6 and 3.9, respectively). The panel rated the semitendinosus muscle at 6 months the most tender (6.3) with a decrease of 1.3 points at 18 months and 1.5 points at 42 months. The 42 and 90 month semitendinosus muscles were rated approximately the same (3.5 and 3.7, respectively).

Dividing each age group according to level of fat indicated a decline in tenderness between 6 and 42 months (6.4, 5.4 and 4.0) for the steaks in the low fat level group (Table IX). The panel scored the steaks from the 6 and 18 month high fat level groups comparable in tenderness (5.8 and 5.7) with a sharp decline in tenderness occurring between 18, 42 and 90 months of age (5.7, 4.1 and 3.6, respectively). The high fat level was slightly favored by the panel for the 18 and 42 month ages. In the 6 and 90 month age groups, the low fat level steaks were favored over those in the high fat level.

TABLE VIII

AGE X MUSCLE MEANS FOR PANEL TENDERNESS[1,2]

Age in Months	6	18	42	90	Avg.
Longissimus dorsi	5.9	6.1	4.6	3.9	5.1
Semitendinosus	6.3	5.0	3.5	3.7	4.6

[1]Averaged over both levels of fat.
[2]Rated on hedonic scale of 8 being extremely tender and 1 equaling extremely tough.

TABLE IX

AGE X FAT LEVEL MEANS FOR PANEL TENDERNESS[1,2]

Age in Months	6	18	42	90	Avg.
Low Fat Level	6.4	5.4	4.0	4.1	4.9
High Fat Level	5.8	5.7	4.1	3.6	4.8

[1]Averaged over both muscles.
[2]Rated on hedonic scale; 8 being extemely tender and 1, extremely tough.

The literature reviewed indicates that the effect of marbling on panel scored tenderness may not be as significant as once thought, but the effect of age is regarded as having a significant effect on tenderness. The average value for all panel members given for tenderness of individual steaks in this study ranged from 7.3 to 1.3. The 1.3 average was for a 42 month semitendinosus steak and the 7.3 was for a 6 month semitendinosus steak, both in the low fat level group. Although the 90 month group was considered the least tender, one longissimus dorsi of high fat level received an average tenderness score of 6.7, a "tender" rating.

The steak groups pattern for tenderness is illustrated in Figure 5. The high fat level longissimus dorsi steaks were least tender of all steak groups at 6 months of age (5.6) but was the most tender of the steak groups at 18 months (6.3) This was the only steak group which followed the pattern indicated by the shear force. The low level longissimus dorsi saw its greatest decrease in tenderness between 18 and 42 months (5.8 and 4.4, respectively). This steak group decreased in tenderness following the pattern of the over-all age means for panel tenderness. The low fat level semitendinosus steaks at 6 months are the most tender (6.6) but decreased very sharply at 18 months (4.9) and again by 42 months (3.5). These steaks deviate from the other steak groups by becoming more tender at 90 months of age (4.3). The high fat level semitendinosus becomes less tender as age increased until the age of 42 months and then appeared to level off (6.0, 5.1, 3.4 and 3.2).

Both the taste panel and the shear values indicated that the greatest decrease in tenderness occurred between 18 and 42 months of age regardless of whether the steaks were divided by age and muscle or age and level of fat.

Panel juiciness and flavor.

The taste panel rated all of the steaks from the forty animals acceptable for juiciness. Average juiciness scores for individual steaks ranged from 3.5, above "moderately dry" (42 month steak) to a 7.0 "very juicy" (90 month steak). The two extreme ratings were for longissimus dorsi steaks of the high fat level group.

The analysis of variance for juiciness indicated a non-significant difference for the four age groups, two fat levels and two muscles (Table X). The analysis of variance indicated a $P < .05$ level of significance for the three-way interaction of age x muscle x fat level (Figure 6). The juiciness score for the low fat level for each muscle paralleled one another after the age of 18 months. In addition, the high level of fat for each muscle followed the same pattern after 18 months of age. At 18 months the high level of fat for each muscle was scored the most juicy. A reversal occurred between 18 and 42 months with the low fat level becoming the most juicy through the 90 month age.

The flavor scores for the four age groups, two muscles and two fat levels and the resulting interactions were not different enough to warrant significance according to the analysis of variance (Table XI) (Figure 7).

The flavor score for individual steaks ranged from 4.8, "slightly desirable" (42 months) to 7.0, "very desirable" (18 months). On the 8-point hedonic scale used by the panel for scoring, even the lowest

TABLE X

ANALYSIS OF VARIANCE FOR PANEL JUICINESS

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	.11	.17	NS
Fat Level	1	.03	.06	NS
Muscle	1	.89	1.64	NS
Age x Muscle	3	.36	.66	NS
Age x Fat Level	3	.16	.27	NS
Muscle x Fat Level	1	.00	.00	NS
Age x Muscle x Fat Level	3	2.04	3.75	.05
Animal in Age x Fat Level	32	.61		
Animal x Muscle in Age x Fat	32	.55		

[1] NS - Not significant at 5 percent level of probability.
.05 - $P < .05$.

FIGURE 6

PANEL JUICINESS AS INFLUENCED BY ANIMAL AGE, MUSCLE AND LEVEL OF FAT

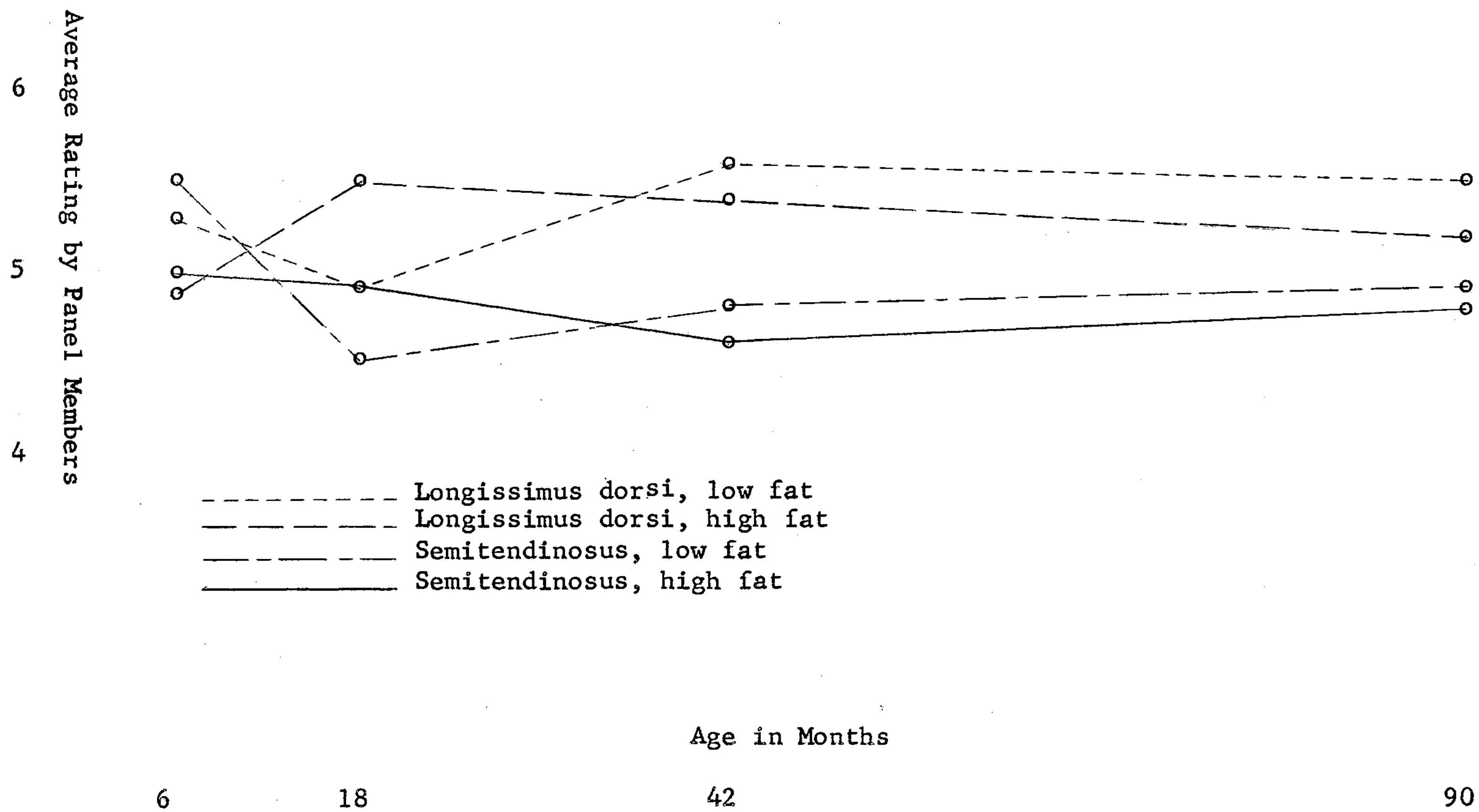


TABLE XI

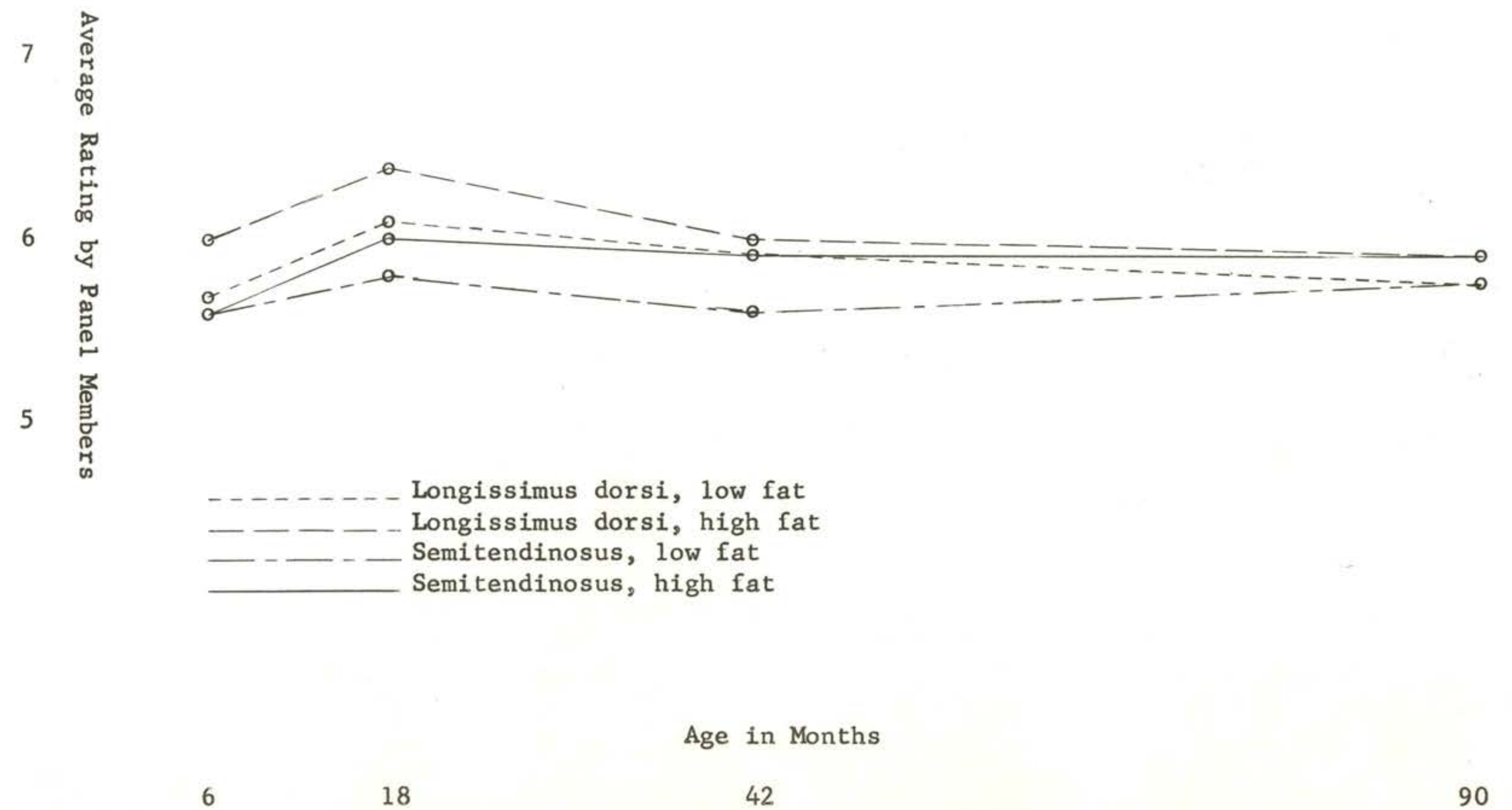
ANALYSIS OF VARIANCE FOR PANEL FLAVOR

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	.42	1.95	NS
Fat Level	1	.13	.62	NS
Muscle	1	.18	1.11	NS
Age x Muscle	3	.08	.49	NS
Age x Fat Level	3	.05	.22	NS
Muscle x Fat Level	1	.19	1.18	NS
Age x Muscle x Fat Level	3	.40	2.52	NS
Animal in Age x Fat Level	32	.21		
Animal x Muscle in Age x Fat	32	.19		

[1] NS - Not significant at 5 percent level of probability.
.05 - $P < .05$.

FIGURE 7

PANEL FLAVOR AS INFLUENCED BY ANIMAL AGE, MUSCLE AND LEVEL OF FAT



rating for flavor was above average. The amount of intramuscular fat did not seem to influence the judges decision. The lowest rating for an individual steak was for a high fat level longissimus dorsi steak and the highest was for a longissimus dorsi steak in the low fat group.

It is very difficult for an individual member of a taste panel to be critical enough to judge tenderness, juiciness and flavor of a single bite of meat. One quality attribute may influence or dominate another.

Simone et al. (1959) and Dunsing (1959) found that the panel over-all eating preference was decided by whether the panel favored tenderness or flavor and juiciness. Those that let tenderness influence their decision the most scored in favor of the younger carcasses (18 months). Those that had stronger preferences for flavor scored in favor of the older carcasses (30 months).

Kropf and Graf (1959) found tenderness related to over-all preference but the correlation of flavor and juiciness was not significantly associated with over-all preference at the 5 percent level. From the data of 334 animals they found greater juiciness was associated with greater tenderness as shown by a significant correlation to sensory tenderness ($r = .53$) and a correlation to mechanical shear of $r = -.54$.

Age and fat level (marbling and finish) have been indicated by the literature as affecting juiciness and flavor scores. Blumer (1963) suggested that juiciness includes both the quantity and quality of the juice. Quantity is more influenced by amount of finish and intramuscular fat, while quality can probably not be separated from the flavor of meat by taste perception. The panel used by Wellington and Stouffer (1959) observed that as the degree of marbling increased there was a significant increase in the juiciness of beef. Doty and Pierce (1961) agreed that the juiciness of broiled steaks was closely associated with fat content but thought that above 7 or 8 percent fat, the juiciness may not be affected by fat level. The panel was unable to detect any appreciable difference in juiciness or flavor when the fat level of the steaks was varied. All steak groups contained less than 8 percent fat except the longissimus dorsi high fat groups for 18 and 90 months of age (11.3 and 10.7 percent, respectively).

Barbella (1939) using ages of 8 to 42 months noted a highly significant effect of fatness on the quality of juice. The author stated that age as a factor seemed to be more important than the fatness factor in affecting quality of juice. Walter et al. (1963) using maturity levels of A, B and F found neither age nor fatness (marbling) significantly associated with juiciness. This general finding of no significant difference for age and/or fatness was also reported by Blackmon (1960) and Tuma (1962).

In the study by Barbella (1939) meat flavor was least desirable under 11 months of age, with flavor increasing from 11 to 30 months, after which there was no change. Age accounted for 83 percent of the variation in flavor, while fatness only 5 percent.

Lowe and Kastelic (1962) reported the scores for flavor on a 10-point scale. The 6 month animals scored 6.6; 18 months, 7.0; and 42-48 months, 6.5 for flavor. Similar flavor socres were found for this study on an 8-point scale for steaks from the 6 month animals were 5.7; 18 months, 6.1; and 42 and 90 months, 5.8.

The flavor analysis of variance for ages was significant at the 5 percent level according to Walter et al. (1963). However, the marbling level did not affect the flavor of the three maturity groups.

Flavor in meat is very difficult for any panel to evaluate satisfactorily. Since these steaks were not aged, many of the panel members may have considered the flavor as mild for all age groups. Therefore, the lack of any strong flavor may have caused the panel members to rate all steaks between "slightly desirable" and "very desirable" on the hedonic scale.

The amount of drip loss depends to a large extent on the proportion of fat and moisture present in the raw steaks. Only a very small percentage (2 - 2.5 percent) of total nitrogen present in the raw steaks was found in the drippings (Doty and Pierce, 1961). Moisture and fat percents show an inverse relationship to one another. Doty and Pierce (1961) thought that juiciness scores of cooked meat do not reflect the amount of free fluid present in the meat but are perhaps more loosely related to some constituent in meat that stimulates salivary secretion.

The proximate analysis was completed in this study because of the relationship of fat and moisture to the organoleptic qualities of juiciness and flavor. The analysis of variance for ether extract indicated all variables highly significant ($P < .01$) with the exception of age x fat level interaction which is significant at the .05 level of probability (Table XII). The percent moisture of the raw product was highly significant ($P < .01$) for all variables except age x fat level which was non-significant at the 5 percent level (Table XIII).

TABLE XII

ANALYSIS OF VARIANCE FOR PERCENT ETHER EXTRACT

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	54.04	37.01	.01
Fat Level	1	232.90	159.52	.01
Muscle	1	52.65	65.32	.01
Age x Muscle	3	11.10	13.78	.01
Age x Fat Level	3	5.00	3.43	.05
Muscle x Fat Level	1	14.88	18.46	.01
Age x Muscle x Fat Level	3	4.78	5.93	.01
Animal in Age x Fat Level	32	1.46		
Animal x Muscle in Age x Fat	32	.81		

[1] .05 - $P < .05$.
.01 - $P < .01$.

TABLE XIII

ANALYSIS OF VARIANCE FOR PERCENT MOISTURE

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	51.09	37.16	.01
Fat Level	1	109.28	79.47	.01
Muscle	1	77.93	75.81	.01
Age x Muscle	3	6.57	6.47	.01
Age x Fat Level	3	2.66	1.93	NS
Muscle x Fat Level	1	9.45	9.30	.01
Age x Muscle x Fat Level	3	5.38	5.30	.01
Animal in Age x Fat Level	32	1.38		
Animal x Muscle in Age x Fat	32	1.02		

[1] NS - Non-significant at 5 percent level of probability.
.01 - $P < .01$.

The analysis of variance for the combined moisture and ether extract indicated no significant difference except level of fat which was significant at the $P < .05$ level (Table XIV). In the combined percentages there is less than 1 percent difference in the means for the four age groups, 6, 18, 42 and 90 months, averaged over muscle and fat level (Table XV). Dividing the ages into fat level groups, there was less than 2 percent difference between the lowest and highest scores (76.1 and 77.8 percent) (Table XVI).

If there were differences in juiciness and flavor as would be expected from the four age groups, two marbling levels and two muscles, the panel did not detect it. The role of the moisture and fat content on juiciness and flavor of a steak is not clearly understood. The taste panel could not discriminate between the apparent differences that did exist in the moisture content or the fat content of the steak groups. It may be that moisture and fat content are confounded so that the sum of the effects was measured and the influence of one could not be separated. The significant level of fat for the combined moisture and fat percentages did not influence the scores appreciably for juiciness and flavor in this study.

TABLE XIV

ANALYSIS OF VARIANCE OF THE COMBINED VALUES FOR PERCENT ETHER EXTRACT AND MOISTURE

Source	df	M.S.	F-Test	Sig.[1]
Total	79			
Age	3	1.42	1.01	NS
Fat Level	1	23.11	16.46	.01
Muscle	1	2.31	3.44	NS
Age x Muscle	3	.69	1.02	NS
Age x Fat Level	3	.61	.43	NS
Muscle x Fat Level	1	.61	.91	NS
Age x Muscle x Fat Level	3	1.18	1.76	NS
Animal in Age x Fat Level	32	1.40		
Animal x Muscle in Age x Fat	32	.67		

[1] NS - Not significant at 5 percent level of probability.
.01 - $P < .01$.

TABLE XV

AGE MEANS FOR COMBINED VALUES OF PERCENT ETHER EXTRACT AND PERCENT MOISTURE[1]

Age in Months	6	18	42	90
Moisture & Ether Extract	77.0	77.3	76.8	76.8

[1]Values for the *longissimus dorsi* and *semitendinosus* muscles including both fat levels.

TABLE XVI

AGE X FAT LEVEL MEANS FOR COMBINED VALUES OF PERCENT ETHER EXTRACT AND PERCENT MOISTURE[1]

Age in Months	6	18	42	90	Avg.
Low Fat Level	76.6	76.9	76.1	76.1	76.3
High Fat Level	77.3	77.8	77.4	77.5	77.5

[1]Averaged over both muscles.

SUMMARY

Warner-Bratzler shear and panel tenderness, flavor and juiciness were scored for the four age groups of 6, 18, 42 and 90 months. Two muscles (longissimus dorsi and semitendinosus) of forty Hereford bovines were used. Each muscle at each age was divided into high and low fat groups according to percent ether extract. The two muscles did not differ significantly in tenderness, flavor and juiciness. Age was an influencing variable for tenderness as scored by both methods. The level of fat was not statistically significantly associated with any of the measurements. However, several interactions did exist especially the three-way classification of age x muscle x fat level. This occurred in both tenderness measurements ($P < .01$) and juiciness ($P < .05$). In reviewing the data and literature for possible explanations, it was thought that the kind, amount and distribution of the connective tissue and muscle fibers may have influenced the shear and taste tenderness. The moisture and fat content as determined by proximate analysis indicated all variables and interactions significant at the $P < .01$ level except age x fat. Combining the percentages of moisture and fat, the analysis of variance indicated only the fat content to be of significance ($P < .01$). It is thought that the confounded effect of fat and moisture may have affected the juiciness and flavor ratings of the panel.

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A P P E N D I X

TABLE XVII

INDIVIDUAL CARCASS DATA
6 MONTH AGE

Animal Number	Cold Carcass Weight	Class Sex	Federal Grade	Marbling Appraised	Maturity Appraised
016	365	Cf(S)	Ch-	Traces	Cf
037	327	Cf(S)	Ch-	Traces	Cf
013	312	Cf(H)	Go+	Traces	Cf
876	265	Cf(H)	Go	Prac Dev	Cf
886	231	Cf(H)	Go	Traces	Cf
059	240	Cf(H)	Ch-	Traces+	Cf
944	362	Cf(S)	Ch	Sli Amt	Cf
093	307	Cf(H)	Ch-	Traces+	Cf
104	331	Cf(H)	Ch-	Sli Amt	Cf
034	355	Cf(H)	Go+	Sli Amt	Cf

18 MONTH AGE

74	550	S	Go	Sli Amt+	B-
62	477	S	Go+	Sli Amt	A
993	673	S	Go+	Sli Amt+	A
5760	541	S	Go+	Sli Amt	A+
60	577	S	Go+	Sli Amt+	A+
4938	691	S	P-	Sli Abun	A
3933	663	S	Ch+	Sli Abun	A
909	494	H	Ch+	Sli Abun	A
3660	608	S	P-	Sli Abun	A
941	713	S	Go+	Sli Amt+	A+

TABLE XVII (continued)

INDIVIDUAL CARCASS DATA
42 MONTH AGE

Animal Number	Cold Carcass Weight	Class Sex	Federal Grade	Marbling Appraised	Maturity Appraised
29-5	655	Cow	Ut+	Sli Amt	D
51-5	616	Cow	Ut+	Sli Amt	D-
29-6	670	H	Go-	Sli Amt	B
22-8	831	H	Com-	Sm Amt	D
10-7	733	H	Com-	Sm Amt	D
54-8	929	Cow	Com	Mod+	E-
63-8	759	H	Ch-	Mod+	C+
7-19	686	H	Ch-	Sli Abun	C
15-7	836	H	Ch-	Sli Abun	C
18-8	879	H	Com+	Mod+	D

90 MONTH AGE

79-1	736	Cow	Ut	Sli Amt	F
31-1	867	Cow	Ut+	Sli Amt	F
42-4	918	Cow	Ut-	Sli Amt	F
73-1	695	Cow	Ut+	Sli Amt	F-
66-2	931	Cow	Ut	Sli Amt	F
24-4	866	Cow	Com	Sli Abun	F
45-4	855	Cow	Com	Sli Abun	F
68-3	913	Cow	Com-	Mod	F
ZH55	1107	Cow	Com-	Mod	F
23-3	1036	Cow	Com-	Mod	F

TABLE XVIII

SHEAR VALUES AS INFLUENCED BY ANIMAL AGE, LEVEL OF FAT AND MUSCLE[1,2,3]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	8.0	14.8	29-5	25.0	27.6
037	14.9	13.2	51-5	27.2	22.8
013	22.5	16.1	29-6	15.7	21.9
876	21.7	17.6	22-8	15.5	28.9
886	15.8	27.8	10-7	26.1	28.2
	LD High Fat	ST		LD High Fat	ST
059	25.5	16.9	54-8	16.4	20.6
944	11.1	16.6	63-8	14.6	22.9
093	23.3	18.4	7-19	18.1	19.2
104	16.3	16.2	15-7	19.2	19.1
034	9.0	15.0	18-8	14.9	21.9

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	7.2	12.6	79-1	28.9	36.4
62	13.3	12.9	31-1	22.7	29.6
993	22.6	19.3	42-4	28.1	38.7
5760	10.3	18.7	73-1	27.8	25.6
60	8.6	13.6	66-2	17.8	26.1
	LD High Fat	ST		LD High Fat	ST
4938	13.8	18.4	24-4	26.6	28.8
3933	12.8	14.6	45-4	21.7	26.1
909	13.6	13.6	68-3	15.1	21.8
3660	7.6	17.5	ZH55	24.9	24.2
941	9.8	18.1	23-3	17.6	18.9

[1]Tenderness measured in pounds of shear force by a Warner-Bratzler shearing device. Average of three cores, nine shears.

[2]Fat level determined by ether extract, left side only.

[3]LD abreviation for longissimus dorsi and ST for semitendinosus.

TABLE XIX

TASTE PANEL TENDERNESS VALUES AS INFLUENCED BY ANIMAL AGE, LEVEL OF FAT AND MUSCLE[1,2,3]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	6.9	6.9	29-5	4.9	4.4
037	6.8	5.8	51-5	3.1	5.5
013	5.0	7.2	29-6	5.2	3.9
876	5.3	7.3	22-8	5.9	2.5
886	7.0	5.6	10-7	2.8	1.3
	LD High Fat	ST		LD High Fat	ST
059	4.8	5.8	54-8	4.8	3.7
944	6.2	7.3	63-8	4.7	2.8
093	4.0	5.6	7-19	5.8	3.8
104	6.3	5.0	15-7	2.7	3.5
034	6.7	6.5	18-8	6.5	3.1

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	6.5	5.2	79-1	3.6	4.8
62	5.5	5.0	31-1	3.6	4.1
993	3.3	4.5	42-4	3.3	2.4
5760	6.7	5.2	73-1	4.3	5.9
60	7.2	4.5	66-2	4.6	4.1
	LD High Fat	ST		LD High Fat	ST
4938	6.2	4.2	24-4	3.0	3.0
3933	6.2	5.8	45-4	3.6	3.1
909	6.0	5.3	68-3	6.7	4.0
3660	6.8	5.8	ZH55	3.0	3.5
941	6.2	4.3	23-3	3.7	2.3

[1]Based on hedonic scale rating with 8 being most tender and 1, least tender.

[2]Fat level determined by ether extract, left side only.

[3]LD abreviation for longissimus dorsi and ST for semitendinosus.

TABLE XX

TASTE PANEL JUICINESS VALUES AS INFLUENCED BY ANIMAL AGE, LEVEL OF FAT AND MUSCLE[1,2,3]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	3.6	4.8	29-5	6.0	5.3
037	5.5	4.4	51-5	5.0	4.9
013	5.5	5.5	29-6	6.3	4.7
876	5.6	6.1	22-8	6.1	4.1
886	6.1	6.6	10-7	4.5	5.0
	LD High Fat	ST		LD High Fat	ST
059	5.3	5.2	54-8	6.0	3.7
941	4.7	6.3	63-8	5.4	3.8
093	5.2	5.0	7-19	6.7	5.5
104	4.6	4.4	15-7	3.5	4.7
034	4.9	4.1	18-8	5.5	5.1

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	4.5	5.2	79-1	5.5	4.1
62	4.3	4.5	31-1	5.0	5.3
993	4.8	4.3	42-4	6.1	4.4
5760	4.7	4.7	73-1	5.0	5.8
60	6.3	3.8	66-2	6.0	5.0
	LD High Fat	ST		LD High Fat	ST
4938	5.5	4.8	24-4	4.9	5.4
3933	6.3	4.8	45-4	5.0	5.0
909	4.8	4.7	68-3	7.0	5.3
3660	6.0	5.8	ZH55	4.8	4.0
941	4.7	4.2	23-3	4.5	4.5

[1]Based on hedonic scale rating with 8 being extremely juicy and 1, extremely dry.

[2]Fat level determined by ether extract, left side only.

[3]LD abreviation for longissimus dorsi and ST for semitendinosus.

TABLE XXI

TASTE PANEL FLAVOR VALUES AS INFLUENCED BY ANIMAL AGE, LEVEL OF FAT AND MUSCLE[1,2,3]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	5.4	4.9	29-5	6.0	5.3
037	5.0	5.1	51-5	5.6	5.6
013	6.2	5.7	29-6	6.0	5.8
876	5.8	6.3	22-8	6.3	5.3
886	6.1	5.9	10-7	5.5	6.0
	LD High Fat	ST		LD High Fat	ST
059	6.2	5.6	54-8	6.4	5.9
944	6.0	6.0	63-8	6.0	5.2
093	6.0	5.2	7-19	6.7	6.0
104	6.0	5.9	15-7	4.8	6.3
034	5.7	5.3	18-8	6.0	5.9

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	6.5	6.0	79-1	5.3	5.5
62	5.5	5.5	31-1	6.0	5.8
993	5.8	5.5	42-4	5.7	5.8
5760	5.8	6.3	73-1	5.9	6.4
60	7.0	5.8	66-2	6.0	5.6
	LD High Fat	ST		LD High Fat	ST
4938	6.3	5.7	24-4	5.3	5.9
3933	6.7	6.0	45-4	5.9	5.7
909	6.5	6.2	68-3	6.7	6.5
3660	6.5	6.0	ZH55	5.9	5.2
941	6.0	6.2	23-3	5.5	6.2

[1]Based on hedonic scale rating with 8 being extremely desirable and 1, extremely undesirable.

[2]Fat level determined by ether extract, left side only.

[3]LD abreviation for longissimus dorsi and ST for semitendinosus.

TABLE XXII

PERCENT MOISTURE VALUES FOR ANIMAL AGE, LEVEL OF FAT AND MUSCLE[1,2]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	74.4	75.1	29-5	71.7	72.4
037	75.3	75.0	51-5	71.2	73.3
013	73.9	73.7	29-6	72.6	72.5
876	72.4	74.3	22-8	71.9	72.8
886	74.5	75.3	10-7	70.8	74.3
	LD High Fat	ST		LD High Fat	ST
059	71.3	71.7	54-8	69.6	71.9
944	72.9	73.8	63-8	69.9	71.5
093	73.4	72.5	7-19	68.7	70.6
104	73.9	74.1	15-7	69.2	68.8
034	72.5	74.1	18-8	69.1	72.4

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	70.6	72.5	79-1	71.4	71.8
62	70.5	71.1	31-1	71.2	71.3
993	70.5	72.5	42-4	70.2	74.8
5760	72.5	72.5	73-1	70.0	72.9
60	73.7	72.3	66-2	69.4	73.8
	LD High Fat	ST		LD High Fat	ST
4938	63.9	71.3	24-4	64.8	69.8
3933	65.4	71.6	45-4	66.3	40.6
909	67.7	71.9	68-3	67.5	68.9
3660	67.5	71.2	ZH55	68.6	71.2
941	67.8	71.5	23-3	68.6	71.8

[1]Fat level determined by ether extract, left side only.
[2]LD abreviation for *longissimus dorsi* and ST for *semitendinosus*.

TABLE XXIII

FAT LEVEL AS DETERMINED BY ETHER EXTRACT[1,2]

6 Months of Age Animal Numbers	LD Low Fat	ST	42 Months of Age Animal Numbers	LD Low Fat	ST
016	1.9	2.4	29-5	2.9	2.7
037	2.1	2.3	51-5	3.4	2.2
013	2.2	2.4	29-6	4.3	4.9
876	2.4	1.9	22-8	4.3	4.0
886	2.7	2.1	10-7	5.4	3.6
	LD High Fat	ST		LD High Fat	ST
059	5.4	5.0	54-8	8.2	5.7
944	4.1	3.5	63-8	7.9	7.3
093	3.8	4.7	7-19	7.9	7.8
104	3.7	4.5	15-7	7.6	6.5
034	3.7	4.2	18-8	7.3	5.9

18 Months of Age Animal Numbers	LD Low Fat	ST	90 Months of Age Animal Numbers	LD Low Fat	ST
74	4.9	5.0	79-1	3.8	3.4
62	5.1	4.1	31-1	4.4	3.5
993	5.4	4.0	42-4	5.6	2.7
5760	5.6	5.2	73-1	5.8	4.7
60	6.3	4.2	66-2	5.9	3.9
	LD High Fat	ST		LD High Fat	ST
4938	14.8	6.9	24-4	12.9	6.1
3933	13.1	6.2	45-4	12.6	7.5
909	9.9	6.5	68-3	10.5	8.5
3660	9.7	6.4	ZH55	9.6	5.8
941	9.1	5.6	23-3	8.1	5.6

[1]Ether extract percentages based on left side only.
[2]LD abreviation for _longissimus dorsi_ and ST for _semitendinosus_.

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