PHYSICAL AND CHEMICAL CHANGES OCCURRING IN BEEF, POST-MORTEM, AS RELATED TO TENDERNESS AND OTHER QUALITY CHARACTERISTICS

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TABLE OF CONTENTS

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

TABLE OF CONTENTS - Continued

LIST OF TABLES

LIST OF TABLES - Continued

LIST OF TABLES - Continued

LIST OF APPENDIX TABLES

LIST OF APPENDIX TABLES - Continued

LIST OF FIGURES

LIST OF FIGURES - Continued

INTRODUCTION

Tenderness is the most important palatability characteristic of beef. Consumers more frequently express disappointment in lack of tenderness than either lack of flavor or lack of juiciness. In general, beef produced today may be considered highly palatable as seen in the decided trend over the past decade of increasing per capita consumption. Beef producers and processors, obviously, are providing beef that meets the consumers' demand. Yet, problems of unexpected toughness in some of the higher priced cuts and the variability in tenderness between identical cuts from different carcasses of the same grade still exist. Differences in tenderness between the different muscles of the beef carcass are real, as established scientifically, and these differences are of importance. In practice, tender muscles go into steaks and less tender muscles go into roasts, stew meat and ground meats. A knowledge of why muscles within a carcass vary in tenderness and why the same muscles of different carcasses differ in tenderness could lead, through further research, to an even greater acceptability of beef. Perhaps beef could be produced more economically, for now most of our beef is fed out in the feed lot, a rather expensive part of the over-all production, with the assumption that increased grade will substantially improve over-all palatability. This broad assumption has brought about the wide-spread practice of finishing cattle by grain feeding. It is obvious that before such an assumption should have had such an influence over production practices, the

validity of that assumption should first have been well established by scientific research. There is a striking lack of research work reported in the literature demonstrating that beef palatability is appreciably enhanced by feeding. The literature that is available, however, does indicate that palatability is somewhat improved by the feeding of concentrate rations prior to the slaughter.

Tenderness of beef has been attributed to the breeding of the animal, feeding, age at time of slaughter and sex. Carcass grade or grade characteristics such as maturity, marbling, color and texture have been related to tenderness. The quantity and character of connective tissue as well as muscle fiber diameter has been associated with tenderness. Method of freezing and method of cooking have been shown to influence tenderness. The study of all of these factors that influence or are associated with tenderness has been helpful in the production and marketing of beef possessing a higher degree of consumer acceptability. Yet research of this nature has failed to show clearly the fundamental nature of tenderness or toughness in beef. Applied type of research has opened several promising avenues of research that might lead to a better understanding of many complexities of tenderness. There is a lack of a fundamental knowledge to explain why beef may be tender or tough. We know how to obtain tender beef by different production and process practices, but we do not fully understand <u>why</u> it is tender.

It has not been possible until the last decade to explore the ultramolecular structure of the muscle cell. Now electron micrographs may be used to locate the myosin and actin filaments on the sarcomers thus allowing identification and definition of some of the many physical and chemical changes that take place in

the muscle during the periods of contraction and relaxation. Many studies of the histological and biophysicochemical properties of muscle have been conducted in the past; most of these studies, however, were conducted on laboratory animals with emphasis mainly toward muscular contraction mechanisms.

Tenderness studies have been confined for the most part to the period following the completion of rigor mortis. Studies of the change in the physical and chemical properties of meat during the pre-rigor, rigor and immediately post-rigor periods have been somewhat lacking.

Muscle tissue contains a large number of proteins that differ in structure, chemical and physical properties and function. There is a present lack of entirely acceptable standard techniques for the isolation, purification and characterization of these proteins. It is not surprising, therefore, that the exact nature of muscle protein changes post-mortem is not clear.

Wierbicki et al. (1954) suggested that initial toughness of meat after slaughter was due to the formation of actomyosin and that the subsequent tenderization was the result of actomyosin dissociation. Wierbicki et al. (1956) later reported data that failed to support their first suggestion about post-mortem. actomyosin dissociation, although the amount of actomyosin seemed to be related to tenderness. Partmann (1963) reported that the actomyosin complex formed during rigor development became dissociated or, at least, may become dissociated easily in aged meat, and that tenderness changes in the aging period were correlated to this process. Furthermore, the same author demonstrated the close correlation in the interactions between adenosine triphosphate (ATP), actin and myosin that took place in living muscle during contraction and extension

and during post-mortem muscle changes. The Partmann (1963) report and the new molecular theory of muscle contraction developed by Davies (1963) who described the anatomical process of contraction by the movement of the thin filaments of actin along the channels between the thick filaments of myosin without overall changes in length allows theorization of why meat should be tough during rigor mortis.

The recent research on extraction and fractionation of muscle proteins according to solubility behavior has been promising. Relationship between the solubility of some intracellular protein components and tenderness and water-holding capacity has been demonstrated by Hill (1962) and Hegarty et al. (1963). Also, the alterations of protein solubility by post-mortem time and conditions have been illustrated by Sayre and Briskey (1963), Kronman and Winterbottom (1960), Weinberg and Rose (1960), Goll et al. (1964) and Khan and Van den Berg (1964).

Starch gel electrophoresis was developed by Smithies (1955) for serum protein studies. This technique showed a greater resolution power than any of the previously used electrophoretic methods, and serum separation was quite successful with this technique. The use of this technique in muscle protein studies has been limited, even though the muscle protein patterns obtained on the starch gel by Hartshorne and Perry (1962), Scopes and Lawrie (1963) and Neelin and Rose (1964) were greater in number and clearer in appearance compared to patterns obtained by previously used methods.

Considering the above factors and others, the present author concluded that a comprehensive study on tenderness, protein, water-holding capacity,

temperature and pH changes during post-mortem might yield information on the nature of post-mortem tenderness change and, at the same time, might give some insight as to why individual carcasses differ in tenderness.

The primary objectives of this study were, therefore, as follows:

1. To study post-mortem changes in tenderness and other organoleptic characteristics, using the Longissimus dorsi muscle of beef carcasses.

2. To study post-mortem changes in solubility of some of the structural and functional muscle protein components and to correlate the quantities of these components to tenderness.

3. To study qualitatively, by using starch gel electrophoresis, the nature of the different muscle protein extracts, to detect any post-mortem changes, and to relate these changes to changes in tenderness and protein solubility.

4. To study post-mortem changes in the water-holding capacity of muscle and to relate such change to palatability characteristics and to pH.

5. To study post-mortem changes in temperature as an index of rate and extent of rigor development and to correlate temperature changes with tenderness.

6. To study post-mortem changes in pH as an index of rate and extent of glycolysis, ATP decomposition and rigor development. Also, to correlate pH readings at different post-mortem intervals and rate of pH drop with tenderness and other factors studied.

7. To study post-mortem changes in cooking loss and to correlate such change to muscle tenderness, juiciness, pH and water-holding capacity.

8. To compare the effect of two methods of cooking (broiling and deep fat frying) on tenderness, flavor, juiciness and other factors studied.

REVIEW OF LITERATURE

The use of the Longissimus dorsi muscle in beef tenderness investigations

The muscles of the beef carcass vary widely in tenderness and in many physical and chemical characteristics. For this reason in a fundamental study it is most desirable to make comparisons between protein components of muscle and between animals on a within-muscle basis.

The L. dorsi is the largest muscle of the beef carcass. It is the major muscle found in the high-priced retail cuts of the loin, rib and chuck. Because of its size in the beef carcass, the L. dorsi can provide a relatively large quantity of muscle for use in experimental work. Data obtained on the L. dorsi should be most meaningful in a practical sense by having been obtained on the largest and one of the most expensive muscles of the carcass.

Satorius and Child (1938) determined the tenderness variability of three different rib cuts from 13 beef carcasses that had been aged 12 days at 2 to 3°C. Their results showed no significant difference in tenderness between the 7 - 8th, 9 - 10th and 11 - 12th rib roasts when only the physical properties of tenderness were measured. Ramsbottom et al. (1945) reported that the L. dorsi muscle was fairly uniform in tenderness, except at the extremities, when compared with other beef muscles. Blakeslee and Miller (1948) used 18 short loin roasts to determine the tenderness of several different grades of beef. Their data demonstrated that the short loins were less tender at the rib end than at the porterhouse end.

Hiner and Hankins (1950) studied the tenderness of nine muscles, including the L. dorsi, from 52 beef animals varying widely in age and sex. Differences in tenderness between samples taken from the 8th rib, shortloin and loin end areas were of no statistical significance from one of the groups studied that consisted of 25 steers averaging 900 pounds in live weight.

Ginger (1957) reported that the L. dorsi muscle presented fewer problems of design for tenderness studies due to its length and width when compared to the Semimembranosus muscle. In later work, Ginger and Weir (1958) studied tenderness variability of the Semimembranosus, Semitendinosus and Biceps femoris using the taste panel and on the Biceps femoris and Semimembranosus using the Warner-Bratzler (W-B) shear measurement. All muscles varied significantly in tenderness throughout their length.

Two muscles, the L. dorsi and the Semitendinosus, from the left side of 12 Hereford heifer carcasses were studied by Mjoseth (1962). Variations in tenderness, gross chemical composition, pH and cooking loss due to carcass and position effect were investigated. The investigation revealed that the effect of position variation in the Semitendinosus muscle was much greater for important variables such as shear force, per cent fat and per cent moisture than was the case in the L. dorsi muscle. In the above study, the amount of variation accounted for by carcass differences in the L. dorsi muscle was greater for all variables except cooking loss than that accounted for by steak position.

The histological study of 50 of the principal beef muscles conducted by Strandine et al. (1949) showed that the cross sectional area of muscles taken anywhere in the muscle except at the extreme ends (origin and insertion) were rather

uniform and presented a regular pattern or arrangement of muscle bundles and connective tissue. Hiner et al. (1953) found no significant difference among fiber size at the third rib, eighth rib, and short loin areas of the L. dorsi. Swanson et al. (1965), however, found a significant difference in cross-sectional area of muscle fibers along the L. dorsi muscle. These researchers reported that the smallest fibers were found over the 12th rib, and the fibers increased in size both anteriorly and posteriorly to this region. The largest fibers were found between the 13th rib and first lumbar vertebra in the short loin region.

Because the short loin is generally considered a more tender cut, Swanson's et al. (1965) work provided support for the observation by Tuma et al. (1962) that no relationship between shear force and fiber diameter existed when the effect of animal age was removed.

Post-mortem change in pH of beef muscle as related to meat quality

The hydrogen ion concentration of meat has a direct or indirect relationship with the commercial value of beef carcasses by influencing color of lean, bacterial growth, organoleptic properties and processing characteristics.

Post-mortem changes in pH were studied by Ramsbottom and Strandine (1949) who found that the muscle pH of six utility grade cattle dropped from about 6.4 at 2 hr after the dressing operation to about 5.5 one day later. Post-mortem changes in pH of Semitendinosus and Biceps femoris steaks removed from two prime, two good and two commercial carcasses were studied by Paul et al. (1952). The authors found that the pH of the raw meat decreased with storage, rapidly for the first 24 hr and more slowly thereafter. The pH values for the six carcasses

were quite close and the averages were: zero hr, pH 6.68; 5 hr, pH 6.50; 12 hr, pH 6.23; 24 hr, pH 5.90; 48 - 53 hr, pH 5.55; and 144 - 149 hr, pH 5.48. Wierbicki et al. (1954) reported that the pH of muscle dropped from 7.3 - 7.4 in the live animal to 5.4 - 5.6 in the carcass within 48 hr after slaughter due to muscle metabolism changing from an aerobic to an anaerobic state. The authors found that the drop in pH was concurrent with the disappearance of ATP and the appearance of lactic acid and inorganic phosphate. Although no direct relationship was shown, the authors concluded that pH and increasing tenderness may be indirectly related. The authors doubted if pH was the primary factor causing increases in tenderness with post-mortem aging. This observation was in agreement with the work of Husaini et al. (1950 b), who conducted a study using 20 animals and failed to show a significant correlation between pH and tenderness of broiled short loin steaks, which were aged at 3.5°C for 14 days.

Hedrick et al. (1959) reported little or no change in tenderness of beef after ante-mortem treatments that raised the pH sufficiently to produce dark cutting beef. High ultimate pH, taken after 24 hr of chilling, and dark meat were the results of continuous excitement over a period of 24 hr by periodic prodding with an electric "hot shot."

In a continuation of tests begun by Paul et al. (1952), Paul and Bratzler (1955) used the L. dorsi muscle of the previously mentioned carcasses plus L. dorsi muscles from two commercial grade cows. The pH was determined on every fourth steak of each muscle. Animal differences in pH values were the only significant values obtained. Average pH values for the six groups

ranged from a high of 5.80 to a low of 5.22. The pH differences due to storage, handling and position on the steak were not significant. The authors felt that two days of cold storage were adequate to complete the initial drop in pH normally observed in beef after slaughter, while nine days were not long enough to cause the slight rise in pH due to increased storage periods observed by Wierbicki et al. (1954).

Briskey (1959) indicated that the initial and ultimate pH values of muscle were critical in determining the time course of rigor; therefore, the factors which predetermine these pH values are of great importance. The author stated that the initial pH was a result of the severity of the death struggle, while the ultimate pH was an indicator of the animal's state of fatigue and level of feeding. He also indicated that the initial pH was not correlated with the ultimate pH. This observation was in line with the finding of Marsh (1954) who reported no relationship between initial and ultimate pH values. The author found that even those muscles with an initial pH of 6.6 - 6.8 apparently contained sufficient glycogen to attain low ultimate pH values. Kronman and Winterbottom (1960) stated that the ultimate pH value of muscle was determined chiefly by the rate of lactic acid production, the buffering capacity of the muscle and the rate of inactivation of the significant glycolytic enzymes.

The relationship between muscle pH and palatability of pork

The relationship between muscle pH, organoleptic and processing characteristics of pork has been investigated.

Judge et al. (1960) reported on the chemical analyses and sensory scoring data obtained from 54 pork loins. Dark, firm muscle was higher in

pH and lower in free water than was light, soft muscle. Water-holding capacity and pH were positively related. A highly significant correlation coefficient of ¬66 was found between pH and tenderness.

Kauffman et al. (1961) used 439 pigs of varying sex, weight and chronological age to investigate the relationships of chilled, aged and cooked pork muscle acidity with palatability and economical traits. Results indicated that increased muscle acidity was significantly indicative of a higher percentage of expressible juice and was characteristic of pale, soft tissue. Darker, drier, firmer muscles exhibited relatively high pH values, shrank less ($P < .01$) during curing and cooking and were more juicy and tender ($P < .01$) when compared to pale, soft muscle.

Lewis et al. (1963) utilized the L. dorsi, Psoas major and Quadriceps femoris muscles of 12 hogs to study the relationships of certain chemical and physical measurements to organoleptic characteristics of pork. The authors found that lactic acid concentration was negatively correlated with tenderness, but not as highly correlated with tenderness as was pH or expressible water. They also found a significant correlation between pH and expressible water.

The relationship between pH and water-holding capacity

The relationship between pH and water-holding capacity has been demonstrated by several investigators. Howard and Lawrie (1956) and Bouton et al. (1957) found that the water-holding capacity or the susceptibility to "drip" after freezing and thawing, as well as flavor and tenderness of beef muscle were all pH-related.

Eight muscles from two cows, a bull, a heifer and a steer were utilized by Swift and Berman (1959). Highly significant correlations of -.89 and .93 between pH and protein content and pH and water retention, respectively, were obtained. The authors demonstrated that the higher the ultimate pH attained by the muscle, the more water the muscle proteins held or "bound."

Penny et al. (1963) demonstrated that injection of adrenaline in beef and rabbits before slaughter improved rehydration, juiciness and tenderness of the rehydrated products. The effect of adrenaline was ascribed to a higher ultimate pH in the meat as a result of glycogen depletion prior to slaughter.

The influence of the pH of fresh meat before heating on the change in water-holding capacity after cooking has been reported by Hamm and Deatherage (1960). Raw L. dorsi muscle from utility cows was adjusted to various pH values and heated to 80°C. The authors found that the pH of meat had a marked influence on water-holding capacity (measured by the press method) before and also after heating. The lowest water-holding capacity of cooked meat was that of meat adjusted to pH 5.0 before heating.

The relationship between water-holding capacity and meat quality

The biochemistry of meat hydration and the relationship of the water-holding capacity to the different characteristics of meat quality has been reviewed by Hamm (1960).

Early work by Satorius and Child (1938) and Hall et al. (1944) indicated no relation between subjective scores for meat palatability and the amount of expressible juice. Gaddis et al. (1950), however, found a low but significant correlation between the amount of press fluid and the juiciness scores in 97 beef

ribs; in 115 lambs and sheep, the authors found no significant correlation. The results obtained by Urbin et al. (1962) indicated a positive relationship between free moisture values and tenderness of the loin-eye in pork.

The effect of heating or cooking on the eating quality of beef has been discussed by Hamm (1960), who suggested that the amount of bound water rather than the amount of expressible juice may be related to juiciness of meat. Ritchey and Hostetler (1964), however, reported that correlations between subjective scores for juiciness and either free or bound water were low and varied irregularly with the different final internal temperatures used in cooking the L. dorsi and Biceps femoris steaks of beef animals. Yet Tannor et al. (1943) and Hardy and Noble (1945) reported a significant correlation between subjective juiciness scores and objective tests for expressible fluid or juice. This finding was in contrast to the report of Ritchey (1965) who failed to find any significant correlations between subjective scores for eating quality in two beef muscles and either bound or free water.

Post-mortem changes in water-holding capacity

Post-mortem change in water-holding capacity is a problem of practical importance in meat processing operations; consequently, the literature provides several interesting reports on the subject.

Wierbicki and Deatherage (1958), Hashimoto et al. (1959), and Hamm (1963) reported that meat hydration dropped very markedly within a few hours after slaughter, reached a minimum in 24 to 48 hr, and increased slowly thereafter. However, the hydration of the aged meat was never as high as that found 1 to 3 hr after slaughtering.

Hamm (1960) reported that the decrease of water-holding capacity after slaughtering was due partly to the drop of pH caused by glycolytic formation of lactic acid. The author reported an experiment in which the press method was used to measure the water-holding capacity of muscle homogenate adjusted to different pH values by adding acid or base; minimum hydration occurred around pH 5.0. Marsh (1952 a,b), however, emphasized the effect of ATP cleavage post-mortem on the decrease in water-holding capacity of muscle. The author's emphasis on ATP water-holding capacity theory was based on observations with rabbit and whale muscle, in which the drop of pH alone was not sufficient explanation for the post-mortem drop in water-holding capacity. This observation was in agreement with Hamm (1963) who reported that the high water-holding capacity of meat immediately after slaughter was largely the result of the presence of ATP. The latter author also stated that two-thirds of the fall in water-holding capacity in beef post-mortem was caused by the breakdown of ATP and one-third caused by the drop in pH as a result of lactic acid formation.

The phenomenon of increased water-holding capacity after "aging" was discussed by Hamm (1960) who reported that the slight rise in pH after "aging" was not the entire explanation. The author reported that only 23 - 33% of the total increase of water-holding capacity of beef muscle after 10 days of aging was due to the increased pH. The author, hence, concluded that other biochemical changes were responsible for the hydration effect of aging. These biochemical changes were explained by the author to be the result of increased net charge of protein due to cleavage of stable (nonelectrostatic) cross linkages or due to proteolytic influences (Hamm, 1963).

Post-mortem changes in beef tenderness

The progressive improvement of tenderness during aging is well established in the literature but there is little information available on the initial tenderness of beef at the time of slaughter and the change in tenderness that occurs during rigor mortis.

Ramsbottom and Strandine (1949) used the L. dorsi muscle from three good carcasses and three utility carcasses to study tenderness changes at the following post-mortem intervals: 2, 5, 8, 11 and 14 hr and also at 1, 2, 3, 6, 9 and 12 days. At the above mentioned intervals, steaks one inch in thickness were removed from the carcass, cooked and evaluated subjectively and objectively for tenderness. The authors found that the L. dorsi steaks were more tender at two hr after slaughter than at any time during the next two days. Steaks removed from the L. dorsi muscle of two carcasses at 3, 6, 9 and 12 days post-mortem were more tender than steaks cut from the loins of two other unchilled carcasses, then held for comparable time post-mortem. Tenderness differences between muscle left intact in the carcass and muscle removed from the carcass immediately post-mortem lessened with aging time and after 12 days post-mortem, muscles left attached to the skeleton were more tender than muscles removed and then held in the cooler.

Recently, in an effort to relate changes in protein solubility to differences in tenderness during post-mortem, Goll et al. (1964) used the Semitendinosus muscle from 15 steers which ranged from 16 to 19 months in age. Nine different sire groups were represented, and animals from the same sire group were sampled at different times post-mortem. The first sample was removed after

15 - 20 min post-mortem, and others were removed at 6, 12, 24, 72 and 312 hr post-mortem. The sampling technique used by the authors was as follows: The Semitendinosus muscle was taken from the left side of each carcass and stored at 4°C until further sampling. At an appropriate post-mortem time for each animal, the Semitendinosus muscle was excised from the right side of the carcass. Thus, the left Semitendinosus muscle of each animal had two steaks removed for W-B shear tests of tenderness and two samples taken for measurements of protein solubility. The corresponding muscle from the right side was excised from the carcass at a certain time post-mortem and had one steak removed for a W-B shear test of tenderness and one sample taken for measurements of protein solubility. Here, the authors found that muscles left attached to the skeleton were least tender during the first 12 hr of post-mortem aging and then gradually increased in tenderness. However, even after 312 hr aging, muscles excised from the skeleton immediately post-mortem were still less tender than muscles that remained with the carcass. This observation was in agreement with that reported by Paul et al. (1952), who found that Semitendinosus steaks decreased in tenderness during the first 24 hr post-mortem and then returned approximately to their original tenderness after 144 - 149 hr. The muscles used in Paul's study had been removed from the skeleton approximately 1 hr post-mortem.

Change in tenderness during aging of beef has been observed by Deatherage and Harsham (1947), who determined tenderness in the loin of 14 beef carcasses at 3, 6, 10, 17, 24, 31, 38 and 41 days post-mortem. The authors found that not all the carcasses increased in tenderness with age throughout the period of observation; i.e. tenderness did not increase smoothly with age.

Husaini et al. (1950 a) found that the meat of 20 carcasses was more tender at 15 days post-mortem than at 3 days. The correlation between initial and final tenderness values was statistically significant but lacked magnitude.

The relationship of muscle proteins to tenderness

Recent interest in the relationship of certain muscle proteins to tenderness has been based on work reported during the late forties and middle fifties. Post-mortem changes in tenderness were observed by Deatherage and Harsham (1947), Ramsbottom and Strandine (1949) and Paul et al. (1952). Husaini et al. (1950 a,b) presented evidence against the previously held view that increased tenderness with aging was due to autolysis by the group of enzymes collectively known as kathepsin. Husaini et al. (1950 a,b) failed to find any increase in the non-protein or proteose-peptone nitrogen fractions during aging of beef. Wierbicki et al. (1954) observed that increased tenderness with aging was not combined with significant changes in the nature of connective tissue as measured by per cent of alkali-insoluble protein and per cent of hydroxyproline. The authors stated that if change in connective tissue was responsible for the increased tenderness during the aging period, then, one should expect connective tissue to break down during the aging period and at least some solubility changes in connective tissues should take place. This observation led the authors to suggest two lines of thought about tenderness changes: 1) initial toughness of meat at slaughter was due to the formation of actomyosin complex from actin and myosin and that subsequent tenderization was the results of actomyosin dissociation and 2) subsequent tenderization involved, rather than extensive dissociation of actomyosin, only a

slight dissociation; this was coupled with, or was brought about by, a redistribution of the ions within the muscle, thus causing increased hydration and tenderness. Later, Wierbicki et al. (1956) reported again that toughness of meat during the onset of rigor mortis was due to the formation of actomyosin; however, actomyosin was not dissociated during post-mortem aging, although the amount of actomyosin seemed to be related to tenderness. The authors therefore suggested that post-mortem tenderization was due to certain ion-protein or protein-protein interactions rather than dissociation of actomyosin.

The insignificant effect of proteolysis in improving tenderness during aging of beef for 16 days was demonstrated by Locker (1960b). The author found a slight decline in both non-protein nitrogen and free amino acid values during rigor, followed by a slow rise to values above the original (at 1 hr post-mortem) during aging. The extremely small rise in values after aging led the author to conclude that proteolysis was most unlikely to be of any importance in the normal tenderization period. This report, however, was in contrast to the finding of Van den Berg et al. (1963) with chicken meat aged at 0°C. Here, the authors observed an appreciable increase in the amount of amino acid nitrogen, as determined by the ninhydrin method, during aging. This report was in agreement with the study of Ginger et al. (1954), who reported that aging beef rib cuts for two weeks at 35°F caused a slight increase in the amount of free arginine, leucine and tyrosine content, as well as in the non-protein nitrogen fraction of the aged meat. The increase noted was interpreted by the authors to be due to proteolytic enzyme activity.

Wang et al. (1957) studied the mode of action of twelve enzyme preparations on the structural organization of beef and the effect of the enzymes on

tenderness. The authors found that enzymic action on the muscle fibers began with disintegration of the sarcolema and nuclei and ended in complete disappearance of the cross-striations. The authors confirmed the early suggestion of Szent-Gyorgyi (1951) that morphological changes in the myofibrils were the result of chemical modification of the actomyosin molecule.

The more recent approach to a better understanding of the nature of meat tenderness has been in the fractionation of muscle cell proteins and the investigation of the quantitative and/or qualitative relationship between the different fractions and tenderness.

Post-mortem changes in the water soluble proteins during aging and freezing were studied by Kronman and Winterbottom (1960). Eight muscles from four animals (one cow and three steers) were used. It was found that aging and freezing of beef muscle for 7 days and 35 days, respectively, rendered protein less soluble in water compared to that of 3 hr post-mortem sample. They reported that the 10 to 30% decrease in protein solubility observed during aging and freezing was due to protein denaturation. The authors also analyzed the fresh, aged and frozen protein extracts by boundary electrophoresis and ultracentrifuge and reported that the patterns obtained by those methods of analysis indicated that some protein components were lost during aging and freezing. Hamm and Deatherage (1960), however, reported that quick freezing and thawing resulted in no considerable denaturation of muscle protein.

Weinberg and Rose (1960) investigated post-mortem changes in protein extractability of chicken breast muscle. Pectoralis muscle of chickens were extracted with phosphate buffer (pH 7.5) in 0.4M KCl (Total ionic strength $\mu = 0.55$),

and the extracts were fractionated by dilution to lower ionic concentrations. It was reported that the amount of nitrogen extracted as "actomyosin" (protein precipitated during dilution of the extracts to ionic strength of 0.225) was increased post-rigor (24 hr post-mortem) compared to pre-rigor extracts (within 30 min after death). However, the amount of nitrogen extracted as "myosin" (protein precipitated during dilution of the extracts from an ionic strength of 0.225 to 0.05) was less post-rigor than in pre-rigor extracts. Although actin was not extracted as such in the author's experiment, the data obtained indicated that more actin was extracted from post-rigor meat and that actin was combined with "myosin" in the extract. This observation led the authors to suggest that tenderization was not merely random autolysis but resulted from a specific cleavage of an actin association responsible for the maintenance of the muscle matrix.

Hill (1962) examined the distribution of nitrogen within characteristically tough (Semitendinosus) and tender (L. dorsi) muscles of different species (cattle, lambs and pigs). The components examined quantitatively for nitrogen content were sarcoplasmic, myofibril, stroma (by difference) and non-protein soluble nitrogen. The author found that the stroma nitrogen and myofibril nitrogen (expressed as per cent of fat-free total tissue nitrogen) were highest in beef muscles and lowest in pig and lamb muscles. Also, on a stroma nitrogen-free basis, beef Semitendinosus was higher in myofibril nitrogen and lower in sarcoplasmic nitrogen content compared to the L. dorsi muscle. These observations led the author to suggest that the amounts of these protein fractions were associated with tenderness.

In an investigation of protein solubility as influenced by physiological

and W-B shear values at the five different post-mortem times studied for muscle removed immediately after death, muscle left attached to the skeleton and muscle excised from the skeleton. Goll et al. (1964) found no pattern of relationship between protein solubility and tenderness. However, the amount of sarcoplasmic protein extracted at any of the post-mortem times was less than the amount extracted immediately after death, and this was alos true of the myofibrillar protein for muscles left attached to the skeleton.

The solubility of different protein extracts from breast and leg muscle of chicken was examined at 30 min and at 2, 4, 24 and 48 hr post-mortem by Khan and Van den Berg (1964). In this study, total extracted nitrogen (soluble in KCl-borate or KCl-phosphate buffer, ionic strength = 1 and pH 7.4) was fractionated into myofibrillar proteins, soluble at $\mu = 0.5$ and insoluble at $\mu = 0.08$, and sarcoplasmic proteins, soluble at $\mu = 0.08$. The authors found that the buffer-extracted nitrogen rapidly decreased during the onset of rigor (2 and 4 hr after death) and gradually increased to a maximum value during post-rigor aging (48 hr). The authors stated that these changes in nitrogen extractability were mainly a result of changes in the solubility of myofibrillar proteins which showed the same patterns of post-mortem change. Quantitative changes in stroma and sarcoplasmic fractions were small. The authors concluded that post-rigor tenderization was the result of the weakening or the breakdown of some bonds which bind myofibrils to the matrix of the muscle.

Electrophoretic separation of rabbit muscle proteins has been conducted by Bate-Smith (1940), Jacob (1947) and Amberson et al.(1949). The identification of new fibrous protein in skeletal muscle by the use of electrophoresis was also

condition in the muscle, Sayre and Briskey (1963) used the L. dorsi from 15 market-weight pigs. The authors found that muscle protein solubility was grossly altered by the conditions of both temperature and pH which existed at the onset of rigor mortis or during the first few hours after death. Sarcoplasmic protein solubility at 24 hr was decreased to 55% of that found at 0 hr in muscle groups exhibiting high temperature and low pH (pH 5.3 - 5.6, temperature $>35^{o}C$) at the onset of rigor mortis. Conversely, only a 17% reduction of sarcoplasmic protein solubility was noted in groups with high pH (pH 6.04) at onset of rigor mortis. Myofibrillar protein solubility ranged from no reduction during the first 24 hr after death, when pH remained high at onset, to 75% reduction in solubility in muscle with low pH and high temperature at the onset of rigor mortis.

The relationship of intracellular protein characteristics to beef muscle tenderness was reported by Hegarty et al. (1963). In this study the carcasses of 20 yearling bulls were aged 7 days, at which time steaks from the L. dorsi were removed; some were used for tenderness evaluation, and others were held in the frozen state for a period of approximately one month for protein fractionation. The authors reported that the ratio of sarcoplasmic nitrogen to total fibrillar nitrogen was correlated with tenderness ($r = -.43$ for shear and $r = .41$ for panel). A higher correlation coefficient between soluble fibrillar nitrogen/total fibrillar nitrogen ratio and tenderness ($r = -.69$ for shear and $r = .59$ for panel) was reported. Also, a correlation of .49, significant at the 5% level, between water-holding capacity and tenderness as measured by the W-B shear technique was found. This finding was in contradiction with the results of Goll et al. (1964) who found insignificant correlations between protein solubility (sarcoplasmic and myofibrillar)

Chromatography also has been used recently for muscle protein investigations. Fujimaki and Deatherage (1964) found that the sarcoplasmic proteins (proteins extracted with water) of beef muscle showed at least 14 fractions immediately after slaughter (about 1 hr post-mortem) when fractionated chromatographically on ion-exchange cellulose. The numbers and levels of eluted peaks in the effluent diagram decreased with aging (7 days at 1 - 3°C) of muscle and freeze-drying of sarcoplasma. The authors concluded that these decreases were due to denaturation. When two beef animals and/or two muscles (L. dorsi and Semimembranosus) were compared, the authors found that quantitative differences appeared even though the qualitative similarities were quite clear in the chromatograms.

Viscosity measurement and muscle protein studies

Brey (1958) defined viscosity of a fluid as a measure of the resistance of the fluid to flow. The methodology, techniques and apparatus used are discussed by the above author and by other, Joslyn (1950).

Perry (1951) demonstrated, by means of viscosity measurements, the effect of adding trypsin to a myofibril solution isolated from rabbit muscle. The author observed that short incubation of a myofibril solution with trypsin caused a considerable decrease in the viscosity of the solution. The author found that trypsin degraded the myofibril and destroyed the actomyosin-forming ability of extracted myosin, yet at the same time had little effect on the ATPase activity. Viscosity measurements were also a valuable technique in understanding the relationship between actomyosin and ATP. Barany et al. (1952) found that ATP lowered the viscosity of actomyosin solutions prepared from beef hearts. By this method, the authors were able to demonstrate the marked activating effect of Mg^{++}

demonstrated by White et al. (1957). The electrophoretic properties of myosin and actin was illustrated by Ziff and Moore (1944) and Spicer and Gergeley (1951).

Smithies' (1955) starch gel electrophoresis technique has been used in recent work for the separation of muscle proteins. Scopes and Lawrie (1963) used vertical starch gel electrophoresis to compare, and detect changes in, sarcoplasmic proteins of beef L. dorsi. Sarcoplasmic proteins were extracted with water from muscle pre-rigor and from muscles held either at 0^{o}C for 20 hr or at 37^{o}C for 4 hr. The authors found that several components were "removed completely or very much diminished by the post-mortem glycolysis" which occurred at 37^{o}C compared either with pre-rigor muscle or with muscle in which the post-mortem pH fall had been relatively slow (at 0^{o}C). The instability of some components was explained by the authors as due to either denaturation or isoelectric precipitation caused by the post-mortem pH fall in muscle. Many of the protein constituents were completely stable, however, and showed no diminution in the starch-gel patterns under the conditions utilized. The authors also identified one of the major components as creatine and phosphoryltransferase. The above method was used by Neelin and Rose (1964) for examining protein extracted from chicken muscle during post-mortem aging. The authors found no detectable, consistent change in the "myofibrillar" proteins during the two-day aging period. Some of the zone appearing on the starch gel were tentatively identified by the authors as myosin and actin. "Sarcoplasmic" extracts of chicken breast muscle, however, revealed significant changes during the tenderization period. These differences were described by the authors in terms of the number of zones appearing or to the intensity of the components.

ions and a smaller inhibitory effect of Ca^{++}ions in the absence of Mg^{++} on a combination between actomyosin and ATP. In the presence of Mg^{++}ions, however, low Ca^{++} concentrations were without effect, but higher Ca^{++} concentrations inhibited the reaction. Szent-Gyorgyi (1960) stated that when solutions of actin and myosin were brought together, a complex, actomyosin, was formed. The viscosity of this complex as reported by the author was higher than that of the sum of the component proteins.

Ultraviolet absorbance and protein concentration

Haurowitz (1963) reported that all proteins strongly absorbed ultraviolet light and that the maximum absorbance was found near 280 m_{μ}. The absorbance at 280 m_{μ} was due to the aromatic residues of tryptophan, tyrosin and phenylalanine; their absorbance maxima, as reported by the author, were found at 280, 275 and 258 m_{μ}, respectively.

Fischer (1963) approximated the protein concentration in his water and salt soluble protein extracts by using the absorbance value obtained at 280 m_{μ}, adjusted with a correction factor obtained from the absorbance value at 260 m_{μ}. Even though the author realized that this determination was not an exact one, he concluded that it was possible to compare the extracts obtained at various times from different chickens, since they were prepared and analyzed under similar conditions.

EXPERIMENTAL PROCEDURE

Animals used

The 36 steers used in this study, of Brahman, Hereford and Angus breeding, were raised at the Everglades Experiment Station. They were approximately 30 months of age at the beginning of the experiment.

Treatment, management and feeding of the animals

In the summer of 1964, the steers were randomly allotted (within weight, grade and breed group) to one of four groups to be treated as shown in Table 1.

Table 1. Experimental design

Lot Number	No. of Animals	Vitamin Treatments
1	9	Control
2	9	A; 25,000 I.U./animal/day
3	9	E; 50 I.U./animal/day
4	9	Combination of 2 and 3

Vitamins were injected at the beginning of the experiment and on 28-day intervals throughout the total feeding period of 120 days.

At the beginning of the study, each steer received 113.4 g of phenothiazine, and all steers were implanted with 24 mg of diethylstilbestrol. The steers were

weighed at the beginning and end of the trial and at every four week interval during the experiment.

The steers were fed on Roselawn St. Augustinegrass pasture. The basal ration was composed as shown in Table 2.

Table 2. Composition of ration

Ingredients	Kg
Ground snapped corn	352
Dried citrus pulp	363
Cottonseed meal (41% c.p.)	182
Mineral mixture[1/]	11

[1/] Mineral mixture of 40% defluorinated phosphate, 22.5% steamed bonemeal, 24.2% salt (iodized and trace mineralized), 2.5% ferrous sulfate, 3.2% copper sulfate, 0.15% cobalt sulfate and 7.45% black-strap molasses.

The steers were hand fed once a day an average of 3.6 kg of the basal ration per day. Fresh water was available at all time.

Slaughter procedure

At the completion of the feeding trial, and for a period of three consecutive weeks, three steers were randomly selected from each of the four different vitamin treatments, weighed (shipping wt.) and transported by truck 440 kilometers to the University of Florida Meat Laboratory at Gainesville. Upon arrival, the twelve steers were weighed (Gainesville wt.). Four steers, one from each lot,

were randomly selected, placed in separate pens, fasted overnight with access to fresh water and slaughtered the following day. The other eight steers were provided with hay and fresh water until the night before slaughtering; the above stated procedure was followed in slaughtering the remaining eight steers. For the first four steers, the Gainesville weight was used for the slaughter weight; for the remaining eight steers, the slaughter weight was determined the night before slaughtering. The twelve steers were slaughtered on three consecutive days.

The animals were slaughtered using routine slaughter procedures, and the hot carcass weights were recorded. The hot right side of each carcass was weighed separately. The left side of each carcass was used in obtaining pH, temperature and other data, while the right side was used chilled and intact for carcass grading and rib eye area measurement.

A strict slaughter time schedule was designed for the three successive slaughter days in order to facilitate data collection and to permit the removal of the muscle samples at rather exact post-mortem times. In this time schedule, periods of one and a half to three hours were provided between slaughterings. To minimize the influence of temperature on rigor development, pH and temperature drop, an exact interval of 70 min was maintained between the time of slaughter and the time each carcass was rolled into the chill cooler.

Chilling, carcass data and aging

All carcasses were chilled at -1°C to 2°C for 48 hr before being graded by a Federal meat grader. At the same time, rib eye tracings at the twelfth rib were obtained, and the chilled right side of each carcass was weighed. Dressing

percentage was calculated using the following formula:

$$\frac{\text{Chilled right side wt. + estimated chilled left side wt.}}{\text{Slaughter wt.}} \times 100 = \text{dressing percentage}$$

After 48 hr of chilling, the left side was rolled into the aging room for holding for a period of 192 hr (8 days). The temperature of the aging room was maintained between 4.4°C and 5.6°C.

Temperature determinations

Temperature readings were obtained with general laboratory mercury thermometers which ranged from -10°C to 110°C with 1°C divisions.

Immediately after sticking, a small slit in the hide was made in the right side of the animal body approximately at the location of the 4th lumbar vertebrae. The thermometer stem was inserted into the L. dorsi muscle perpendicular to the back bone to a depth of eight cm. Two min later, the first temperature was recorded and the thermometer removed to allow further slaughtering procedures. At 55 min post-mortem, the thermometer was inserted in the left side at approximately the same position as stated for the right side. The thermometer remained in this position until temperature readings were completed.

After the first temperature reading, temperature measurements were taken each successive hour on the hour for 24 hr. After the 24th hr reading, observations were recorded every 4 hr for an additional 24 hr.

pH determinations

For pH measurements, a Beckman expanded scale pH meter (Model 76) was used. The pH meter was equipped with a flat bulb combination electrode,

sensitive for surface pH measurements, and a thermocompensator that provided temperature correction for pH measurements.

Starting at the 9th rib and continuing toward the 8th, a small piece of the L. dorsi was removed, and surface pH readings were made on the fresh cut surface immediately. In the same way, pH measurements of the L. dorsi muscle were made on the 36 animals at one-hr intervals; reading began one hr after slaughter and continued through the 24th hr. Readings were then taken every 4 hr for the next 24 hr. The final pH reading was taken at 192 hr post-mortem.

Scheme for steaks removed from the Longissimus dorsi muscle for the different studies conducted

Exactly one hr after slaughtering, the left side of the beef carcass was ribbed by cutting between the 9th and 10th ribs perpendicular to the long axis of the L. dorsi muscle and following the contour of the 9th rib. Cutting toward the posterior end of the animal, four adjacent 2.54 cm thick boneless steaks were removed. Another four boneless steaks of the same thickness were removed at 24, 48 and 192 hr post-mortem.

The steaks were numbered consecutively 1 through 16 starting with the most anterior steak and proceeding posteriorally as shown in Fig. 1.

Steaks numbered 1, 8, 12 and 16 were wrapped immediately in freezer paper and were identified with the following data: slaughter number, animal number and post-mortem interval. These steaks were then frozen and stored at -24^{o}C until used for the protein studies. The remaining twelve steaks were used immediately after removal from the muscle for the determinations below.

Steaks numbered 2, 7, 11 and 15 were used fresh and uncooked for the

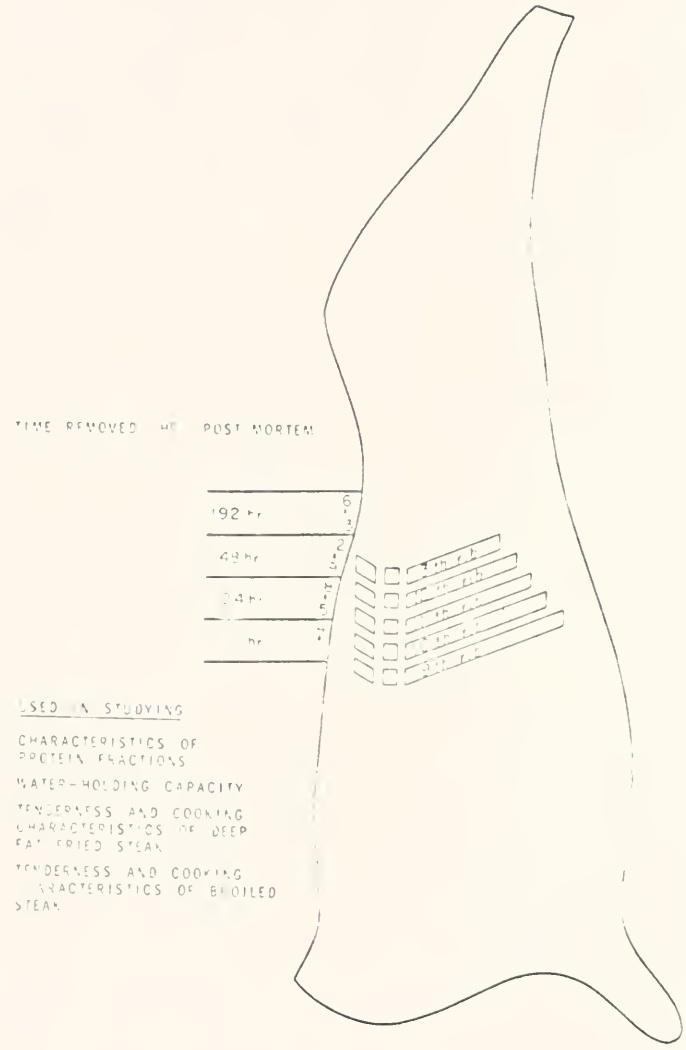

Fig. 1. Schedule of removing L. dorsi steaks for studies conducted.

water-holding capacity determination. The other eight steaks were used for cooking time, cooking loss, taste testing by trained panel and W-B shear determinations. Steaks numbered 4, 5, 9, 13 and 3, 6, 10, 14 were cooked by broiling and deep fat frying, respectively.

Cooking

Two of the four L. dorsi steaks, removed at 1, 24, 48 and 192 hr postmortem, were used for cooking. The steaks were trimmed of all exterior fat and connective tissue and weighed to the nearest gram. The steaks were cooked by two methods, broiling and deep fat frying.

In broiling, a meat thermometer (Weston model 2261, 5 in. stem, calibrated from 0^{o}F to 220^{o}F) was inserted into the most central position (depth, height and width being considered) of the steak for use in recording initial and final internal temperature. The steaks were then broiled in a pre-heated electric oven. As the internal temperature of 76.6^{o}C was reached, the steaks were removed from the oven, placed on plates, immediately weighed and data recorded. The difference between raw and cooked weights was used to calculate per cent cooking loss. Individual steak broiling times were recorded.

A General Electric (Model CK20, 230 volt, A.C.) deep fat fryer was used for frying steaks to an internal temperature of 76.6^{o}C. The commercial type hydrogenated vegetable oil was pre-heated to 149^{o}C and that temperature automatically maintained within a plus or minus range of 1^{o}C.

Organoleptic panel and Warner-Bratzler shearing

The cooked, weighed steaks were cooled to room temperature for taste

panel and shear determinations. Two cores 1.27 cm in diameter were removed from the dorsal, medial and lateral areas of the steaks. Using the W-B shear, each core was then sheared twice, giving a total of twelve values per steak. The twelve values were averaged to give the shear score for the steak.

After cores for shear determinations were taken, the remaining portion of the steak was divided into four sections with numbered portions going to numbered members of the taste panel. Each panel member received a portion from the same position of each different steak. The taste panel members determined tenderness, flavor and juiciness using the palatability scale shown in Appendix Table 45 .

Water-holding capacity determinations

In the present study, water-holding capacity (WHC) is expressed in terms of the amount of free or expressable water and bound water relative to the total moisture content of the muscle. The pressing method of Grau and Hamm (1953) with the modifications of Ritchey and Hostetler (1964) was used for the WHC determinations of this study. The following procedures were used.

One of the four steaks cut from the L. dorsi muscle on the left side of each carcass at the post-mortem intervals of 1, 24, 48 and 192 hr was used for this determination. The removed L. dorsi muscle was trimmed of external fat and connective tissue. Using a Hamilton Beach meat grinder, the sample was ground three times and mixed thoroughly after each grinding. The food grinder was washed and dried thoroughly between each sample grinding.

Total water was determined by the AOAC (1960) method using triplicate 10-g samples.

In determining bound water, triplicate sub-samples of 5 ± 0.1 g were weighed on aluminum foil 7 cm in diameter; a second piece of foil was placed on top of the sample. The sample enclosed in the two pieces of foil was placed between two Whatman No. 41, 11.0-cm filter papers. Using a Carver laboratory press (Model B), the sample was immediately pressed for one min at 5,800 kg force. After pressing, the two pieces of filter paper were removed from the foil enclosed sample. The fragments of meat extending beyond the foil were trimmed away, and the foil coverings were pulled apart. The pressed sample was scraped into a previously dried and weighed drying dish. The dish and sample were weighed to determine the sample weight. Residual moisture or "bound water" was determined by the AOAC (1960) method.

Free water was determined by subtracting bound water from total water.

Muscle proteins studies

The frozen, stored L. dorsi steaks of 20 steers (5 steers randomly selected from each treatment) numbered 1, 8, 12 and 16 (taken at 1, 24, 48 and 192 hr post-mortem, respectively) were used for this study.

Preparation of samples

The L. dorsi steak was removed from the freezer and placed in a 3.3°C refrigerator for approximately 10 hr before extraction. Fat and connective tissue were separated as completely as possible from the muscle while still partially frozen. The trimmed, diced muscle was then ground three times in a Hamilton Beach meat grinder and mixed thoroughly after each grinding. From the paste thus obtained, the following sub-samples were taken: two g for total tissue nitrogen analysis, five g for the extraction and quantitative determination of nitrogen in

buffer soluble and buffer insoluble protein extracts, five g for the extraction and quantitative determination of nitrogen in water soluble protein extracts, five g for the extraction and qualitative study of buffer soluble protein extracts by starch gel electrophoresis and five g for the extraction and qualitative study of water soluble protein extracts by starch gel electrophoresis.

Extraction and fractionation of buffer soluble, buffer insoluble and water soluble proteins

The classification and solubility properties of muscle proteins as outlined by Szent-Gyorgyi (1960) were the bases for the methods of extraction used in this study. The extractability of these proteins as determined by Khan (1962) and Helander (1957) was also considered. By combining and modifying the techniques used by other workers (Weinberg and Rose, 1960; Sayre et al. 1963; Hegarty et al. 1963; Fujimaki and Deatherage, 1964; Goll et al. 1964 and Khan and Van den Berg, 1964) a method for the extraction and fractionation of buffer soluble, buffer insoluble and water soluble proteins was adapted and used as shown in Figs. 2 and 3 respectively.

To avoid protein denaturation, an ice bath and a cold room at $7 \pm 2^{o}C$ were used for the extraction and centrifugation procedures.

Nitrogen analysis

All nitrogen determinations were made using a macro-kjeldahl method (AOAC, 1960). Protein values were estimated by multiplying the nitrogen value by a factor of 6.25. Nitrogen determinations were made in duplicate.

Preparation of potassium chloride-potassium phosphate buffer

This high ionic strength buffer was used for the extraction of buffer soluble

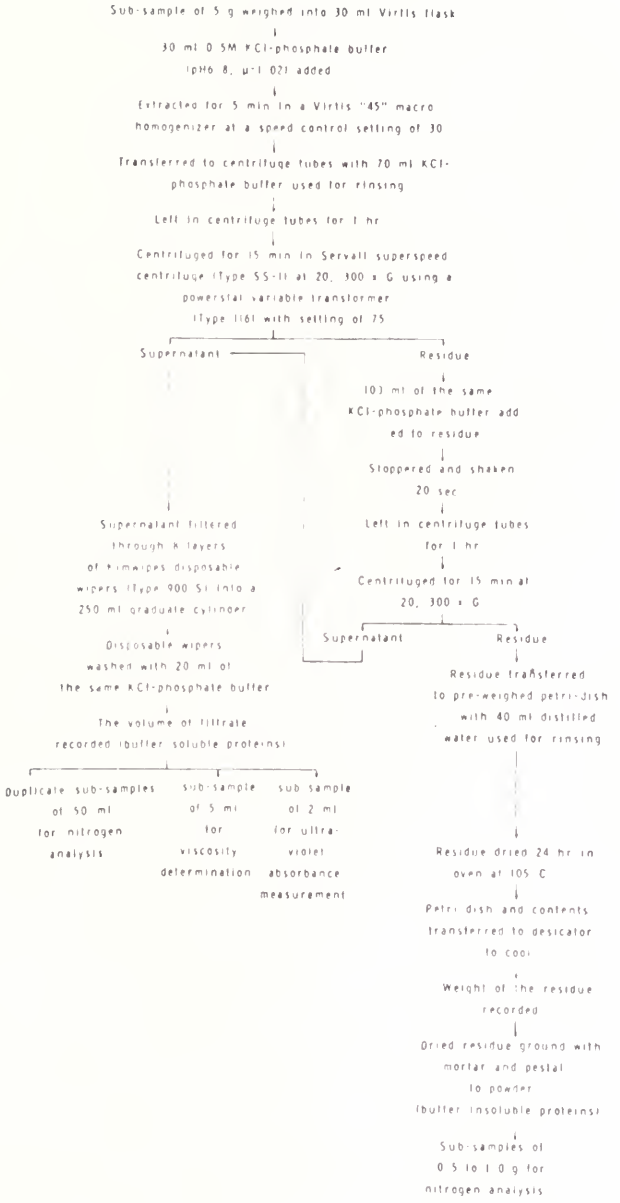

FIG. 2 Scheme for the extraction of buffer soluble and buffer insoluble proteins and other quantitative and qualitative analysis conducted

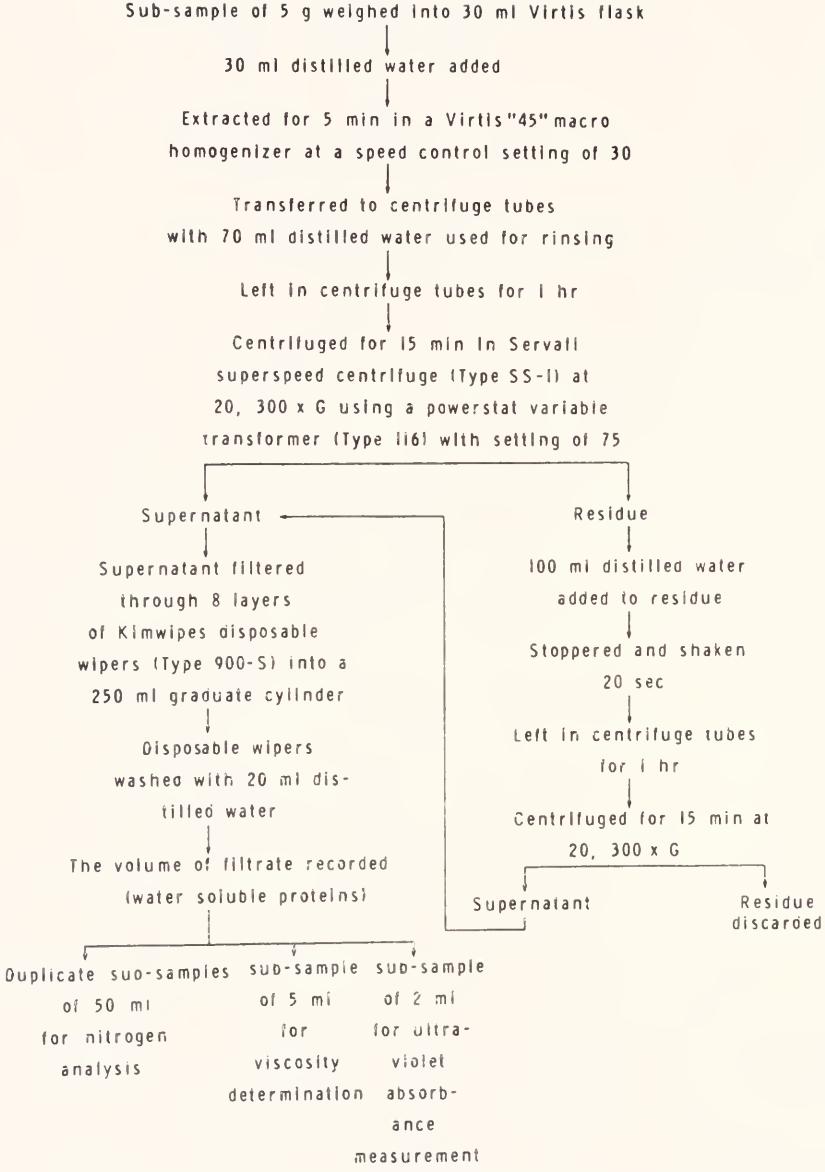

Fig. 3. Scheme for the extraction of water soluble proteins and other quantitative and qualitative analysis conducted.

proteins. This buffer was made by dissolving the following reagents (ACS) in a liter of distilled water;

a. 17.69183 g (0.13M) monobasic potassium phosphate (KH_2PO_4) crystals.

b. 22.64379 g (0.13M) dibasic potassium phosphate (K_2HPO_4) powder.

c. 37.27850 g (0.5M) potassium chloride (KCl) crystals.

The calculated ionic strength (μ) of this buffer was 1.02, and the measured pH of this buffer solution was 6.8.

In order to minimize experimental error in making up the buffer, and due to the large quantities of buffer required throughout the study, it was desirable to make the above buffer in stock solution. The stock solution was kept in 25-L bottles and diluted accurately to the desired concentration when used.

Viscosity determinations

The viscosities (η) of the buffer and water soluble protein extracts were determined by the use of a Cannon-Fenske viscometer (size 100). Viscosity measurements were conducted on all the buffer and water soluble protein extracts obtained from the 1, 24, 48 and 192-hr post-mortem L. dorsi samples of the 20 animals used in this study.

The temperature of the extracted solutions was adjusted to 17°C before each measurement. Using a volumetric pipette, 5 ml of the solution was then transferred to the viscometer. The time in seconds required for the liquid to flow through the capillary tube was recorded. The final reading for each sample was obtained by averaging the two readings that agreed within one second. The time required for 5 ml of distilled water at 17°C was also determined.

For the calculation of the viscosity of the buffer soluble protein extracts, a density measurement of the phosphate buffer at 17°C was required; a Westphal balance (No. 683) was utilized for this determination.

The viscosity in centipoise (cps) for the extracted solutions was calculated using the ratio of viscosity coefficients given below:

1. Viscosity calculation for the buffer soluble protein extracts

$$\frac{\eta_1}{\eta_2} = \frac{\rho_1 t_1}{\rho_2 t_2}$$

Where:

η_1 = viscosity in cps for buffer soluble protein extracts at 17°C.

η_2 = viscosity in cps for H_2O at 17°C = 1.0828 (Hodgman, 1961-1962).

ρ_1 = density in g/ml for buffer soluble protein extracts at 17°C = 1.0536 (as measured).

ρ_2 = density in g/ml for H_2O at 17°C = 0.99880 (Hodgman, 1961-1962).

t_1 = time in sec required for buffer soluble protein extracts to flow through the capillary tube of Cannon-Fenske viscometer.

t_2 = time in sec required for H_2O to flow through the capillary tube of Cannon-Fenske viscometer.

2. Viscosity calculation for the water soluble protein extracts

The above ratio of viscosity coefficients was also used for the calculation of the viscosity of the water soluble proteins extracted. Because water was used in the extracting of these proteins and because of the low nitrogen concentration in the extracted solutions, it was assumed that $\rho_1 = \rho_2$. Therefore, the final coefficient ratio used was

$$\frac{\eta_1}{\eta_2} = \frac{t_1}{t_2}$$

Where:

η_1 = viscosity in cps for water soluble protein extracts at 17°C.

η_2 = viscosity in cps for H_2O at 17° C = 1.0828 (Hodgman, 1961-1962).

t_1 = time in sec required for water soluble protein extracts to flow through the capillary tube of Cannon-Fenske viscometer.

t_2 = time in sec required for H_2O to flow through the capillary tube of Cannon-Fenske viscometer.

Ultraviolet absorbance measurements

The ultraviolet absorbance of the buffer and water soluble protein extracts was determined by the use of a Beckman spectrophotometer (Model DU) with silica cuvettes. Ultraviolet absorbance measurements were conducted on all the buffer and water soluble protein extracts obtained from the 1, 24, 48 and 192 hr post-mortem L. dorsi samples of the 20 animals used in this study.

For determination of ultraviolet absorbance, a 0.2 ml aliquot was diluted with 2.5 ml distilled water (1:12.5 dilution) and examined at 260 and 280 millimicrons. Distilled water was used as a blank for both buffer and water soluble protein extracts.

Starch gel electrophoresis studies

The electrophoretic method utilized in this study was that of Smithies (1955) in which he introduced starch gel as the supporting material. The improved (vertical) method (Smithies, 1959), and the discontinuous system of buffers with platinum electrodes of Poulik (1959) was used in this qualitative study. Some of the modifications and procedures used by Pert et al. (1959); Pierce and Free (1961); Tsuyuki et al. (1962) and Neelin and Rose (1964) were also employed.

Preparation of muscle protein extracts for starch gel electrophoresis analysis

Two sub-samples of 5 g of the paste obtained from the frozen stored L. dorsi steaks numbered 1, 8, 12 and 16, taken respectively at 1, 24, 48 and 192 hr post-mortem, were used for the extraction of buffer and water soluble proteins for starch gel electrophoresis studies. The scheme used for the extraction of buffer and water soluble proteins in this qualitative study is shown in Figs. 4 and 5 respectively.

Precautions against protein denaturation were the same as previously stated for the extraction and fractionation of buffer and water soluble proteins.

Preparation of electrolyte buffers

Two different electrolyte buffers were required for the electrophoretic fractionation of proteins investigated.

The tris-citrate buffer electrolyte solution, used in making the starch gels, was made by dissolving 9.2 g tris (hydroxymethyl) amino methane (Trizma base, Sigma Chemical Company, St. Louis, Missouri) and 1.05 g anhydrous citric acid ($H_3C_6H_5O_7$) in 1 L of distilled water. The pH of this buffer solution was 8.8.

The borate buffer electrolyte solution, used in the electrode vessels, was made by dissolving 18.5 g boric acid (H_3BO_3) crystals (ACS) and 2.0 g sodium hydroxide (NaOH) pellets (ACS) in 1 L of distilled water. The pH of the solution obtained was 7.0.

For the same reasons as previously stated, it was desirable to make the above electrolytes in stock solutions. The stock solutions were kept in 10 to 20 L bottles and solutions were diluted accurately to the desired concentration when used.

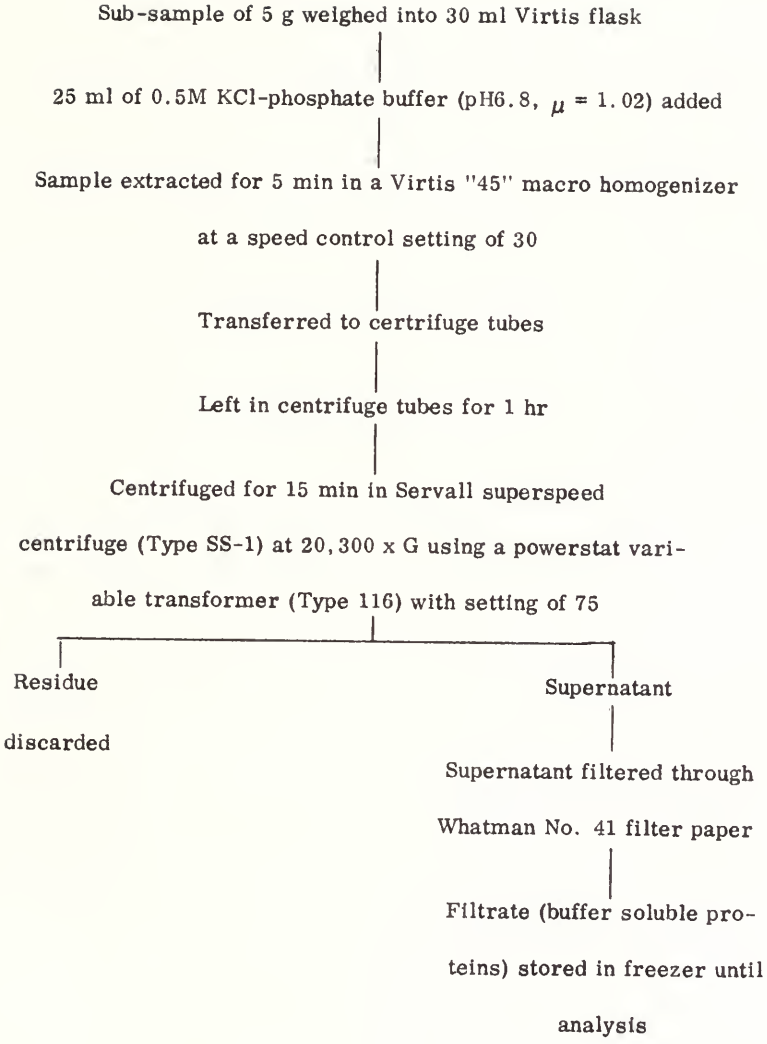

Fig. 4. Scheme for the extraction of buffer soluble proteins for starch gel electrophoresis analysis.

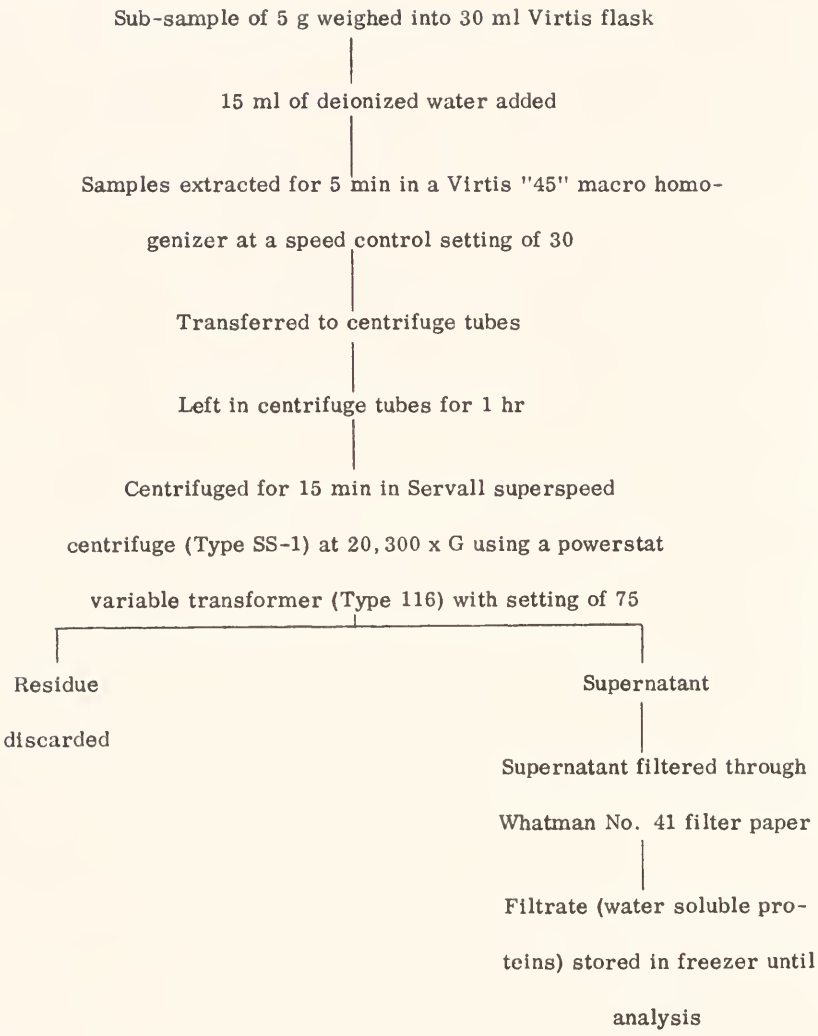

Fig. 5. Scheme for the extraction of water soluble proteins for starch gel electrophoresis analysis.

Preparation of the starch gel

Gels were prepared from hydrolysed starch especially prepared for starch gel electrophoresis (Connaught Medical Research Laboratory, Toronto, Canada). The standard procedure used in making up the gels was as follows:

Exactly 500 ml of the tris-citrate buffer was added to 70 g hydrolysed starch in 1000-ml Erlenmeyer flask. The starch and buffer suspension was gently heated over a burner with continuous vigorous agitation until the granules were ruptured and a clear solution obtained. Degassing was then conducted by suction through a one-hole rubber stopper inserted into the neck of the flask and connected through a suitable trap to a water aspirator. The resulting viscous, translucent fluid was then poured into a rectangular plastic tray (32 cm long, 12.2 cm wide and 0.7 cm deep). The surface of an 8-sample gel saw cuts cover (Otto Hiller, Madison, Wisconsin) was layered with a few drops of mineral oil and then heated in an oven at 70°C. The preheated gel cover was used to cover the hot gel. Weights were placed on the four corners and the middle of the plastic cover to ensure a uniform gel thickness and to prevent the formation of bubbles. The gel was then allowed to cool and solidify overnight at room temperature.

Application of samples and electrophoresis conditions

After removing the cover and trimming the excess of gel from all sides of the tray, the thawed protein extracts were introduced carefully into the sample slots by means of disposable capillary pipettes. Each sample slot held approximately 0.06 ml of the protein extract. A liquid was made of approximately 227 g paraffin and 100 g vaseline, heated in an oven at 70°C; a portion of this liquid was carefully poured to form a thin film on the entire surface of the gel. The end plates

of the gel tray were removed, and the gel was placed vertically between two buffer chambers. Electrical contact between the gel and the sodium hydroxide-borate buffer in the chambers was made through wicks composed of 3 layers of Whatman No. 2 filter paper. Platinum electrodes were used in the buffer chambers.

Electrophoresis was carried out at 7 $\pm$ 2°C with a current of approximately 45 - 22 ma and voltage of 18 - 32 V/cm across the gel for periods of 6 to 8 hr. A regulated power supply unit and a vacuum tube voltmeter (Model IP32, and IM11, respectively, Heath Company, Benton Harbor, Michigan) were utilized for supplying, regulating and checking the voltage and current.

Staining and washing procedures

After completion of electrophoresis, the paraffin-vaseline film was removed, and the gel carefully transferred to a slicing tray. The gel was sliced lengthwise with a fine fishing thread. The horizontally sliced strips, with the cut surface up, were stained for approximately 1 min with a saturated solution of Amido black 10B (Naphthol blue black, E. Merckag, Darmstadt, Germany) in methanol-water-acetic acid solvent (5:5:1 by volume). To remove excess stain from gel strips, the strips were washed with solvent for a period of 20 to 30 hr by placing them in a tank of an automatic gel washing machine (Otto Hiller, Madison, Wisconsin). By means of a centrifugal pump provided with this washing apparatus, the stain was continuously removed from the solvent by recirculation through a drum of activated charcoal. A gentle stream of colorless solvent over the gel strips was provided by means of a multiple hole tubing in the washing tank.

The stained, washed gel was then diagrammatically sketched, wrapped in

Saran Wrap and identified with the following data: gel run, slaughter number, animal number and type of extract. The identified gels were stored in the refrigerator at 3.3°C.

System of sample analysis and data recording for the starch gel electrophoresis

Water and buffer soluble protein extracts were analysed by the starch gel electrophoresis technique on alternate days. Starting at the right end of the gel (slot no. 1) the following sample order was used in filling the eight sample slots: 1, 24, 48, 192, 1, 24, 48 and 192-hr post-mortem samples. Data were recorded as shown in Fig. 6.

Diagrammatic sketch for the gel

The faint appearance of several patterns on the gel strips and the noticeable fading of those patterns shortly after removing the gel from the washing solvent were recognized in preliminary experimentation with the technique. The above two factors, combined with the difficulty of handling the fragile gel strips, made it necessary to make a diagrammatic representation for the different patterns obtained on the gel.

For each sample four locations on the two gel strips were obtained by running the sample in duplicate per gel; the clearest separation from these four locations was sketched in the following manner:

A base line representing the original sample slots in the gel was drawn on the data sheet. A portion of this horizontal line was divided into four 0.9-cm parts with each part representing 1, 24, 48 and 192-hr post-mortem intervals respectively. With the use of a ruler (0.1-cm divisions), the distance of each pattern on the gel from the origin at the four intervals examined was measured, and a line

Starch gel No. _____ Date _____

Slaughter No. _____

Animal No. _____

Type of extract _____

	Start	Finish
Voltage reading (power supply unit)	_____	_____
ma reading (power supply unit)	_____	_____
Voltage across starch (vacuum tube voltmeter)	_____	_____
Time	_____	_____

Slot No.	Sample No.
1	
2	
3	
4	
5	
6	
7	
8	

Fig. 6. Starch gel electrophoresis data sheet.

representing each band was drawn at a distance from the base line equal to that measured on the gel strip. The intensity and width of the different bands were also maintained in this diagrammatic sketching. In many cases it was necessary to run the extracts more than one time to get an adequately clear separation.

Statistical analysis

All data were punched on cards for electronic computing on the IBM 709 computer. The statistical methods (Snedecor, 1959) used in analyzing the data were:

1. Analyses of variance and covariance were used to determine if significant differences existed among the different traits studied.

2. Simple correlation coefficients were computed to determine if relationships between certain variables existed.

3. The stepwise regression analysis was also employed in this study. The stepwise regression analysis which was used picks out the independent variable having the highest simple correlation with the dependent variable. It then proceeds in a stepwise manner to add one independent variable at a time which, when combined, gives the best estimate of the dependent variable. The next variable selected is that variable having the highest partial correlation with the dependent variable and independent of those factors in the equation. This process continues until it is ascertained that addition of any of the remaining independent variables will not significantly improve the fit of the regression equation.

Partial regression coefficients show the effect of an independent variable on a dependent variable, with other variables held constant.

RESULTS AND DISCUSSION

The effect of feeding treatment on rate of gain, in-transit shrink and slaughter characteristics

Rate of gain, per cent in-transit shrink and slaughter characteristics of the four lots are summarized in Table 3. The significance of differences in response to the four treatments are shown also in the same table.

Only slight differences in average daily gain, carcass weight, dressing per cent, liver per cent, and carcass shrink were found between the four lots. The differences lacked statistical significance, however. Small differences in per cent in-transit shrink were observed between the four groups; analysis of variance showed that the differences were not significant.

The effect of feeding treatment on carcass characteristics

Table 4 gives the mean values and the significance of differences between the four lots in carcass characteristics.

Only insignificant differences in carcass characteristics were found among the four treatments.

Feeding treatment had no effect on degree of marbling, conformation, carcass maturity or color, texture and firmness of the lean. Carcass grades were similar for all lots and the color of the external finish was not influenced by feeding treatment. Differences between lots in rib eye area, fat thickness over the rib eye and estimated kidney knob were not significant. Differences

Table 3. Mean values and significance of difference among the four treatments in feed lot gain, in-transit shrink and slaughter characteristics.

Treatment No.	1	2	3	4	Significance of difference
No. of steers	9	9	9	9	
Initial wt., kg	364.9	364.4	361.4	365.1	----
Final wt., kg	460.7	482.3	467.2	471.2	----
No. da. on feed	116	116	116	116	----
Av. daily gain, kg	.82	1.02	.91	.91	N.S.
In-transit shrink, %	4.84	7.31	6.32	6.75	N.S.
Chilled carcass wt., kg	261.5	264.3	259.9	271.1	N.S.
Dressing, %	60.9	59.9	59.6	61.1	N.S.
Liver, %	1.05	1.12	1.07	1.11	N.S.
Carcass shrink, %	1.58	1.35	1.31	1.17	N.S.

Table 4. Mean values and significance of difference among the four treatments in carcass qualities and indices of meatiness. [1/]

Treatment No.	1	2	3	4	Significance of difference
No. of steers	9	9	9	9	
Marbling	10.33	9.33	10.00	10.33	N.S.
Conformation	14.22	14.22	13.33	14.56	N.S.
Carcass maturity	3.33	3.78	4.11	3.78	N.S.
Color of lean	4.44	3.78	4.00	3.89	N.S.
Texture of lean	4.78	4.78	4.78	4.44	N.S.
Firmness of lean	5.00	4.67	5.22	4.89	N.S.
Color of fat	2.56	2.22	2.78	2.67	N.S.
Carcass grade	13.89	13.44	13.33	14.00	N.S.
Rib eye area, (sq cm)	27.17	27.91	26.14	27.81	N.S.
Adj. fat over eye, (cm)	.90	.78	.71	.90	N.S.
Est. kidney fat, %	2.39	2.44	2.56	2.89	N.S.
Est. yield, %	51.20	51.38	51.07	50.70	N.S.
Yield grade	2.83	2.75	2.88	3.06	N.S.

[1/] See Appendix Table 44 for scales used in evaluating carcass characteristics.

between lots in estimated per cent of boneless, fat-trimmed meat from the round, rump, loin, rib, and chuck lacked significance.

Post-mortem changes in the pH of the Longissimus dorsi

Fig. 7 shows the pH curve obtained by plotting the average pH values of the 36 animals against the post-mortem time.

The graph illustrates that the average pH values of the L. dorsi decreased with time post-mortem, rapidly for the first 15 hr and slowly thereafter; minimum values were obtained at the 192 hr post-mortem observation. These results are in agreement with the reports of Paul et al. (1952) and Paul and Bratzler (1955).

The correlations between average pH values of the L. dorsi at 1, 24, 48 and 192 hr post-mortem are presented in Table 5. The correlations between the average pH value at 1 hr and the pH values at 24, 48 and 192 hr were low and insignificant. pH values obtained at either 24 or 48 hr post-mortem were not closely related to pH values obtained at 192 hr post-mortem. These results support the report of Briskey (1959) and the finding of Marsh (1954) who found little relationship between initial and ultimate pH values. Huffman (1962) found a highly significant negative correlation of -.92 between initial and ultimate pH values in sheep, but the lack of agreement between his work and that reported herein may be attributed to either species differences or to Huffman's (1962) attempt to alter rate of pH drop or rate of rigor development by pre-rigor treatments.

A significant correlation ($P<.01$) of .64 was found between average pH

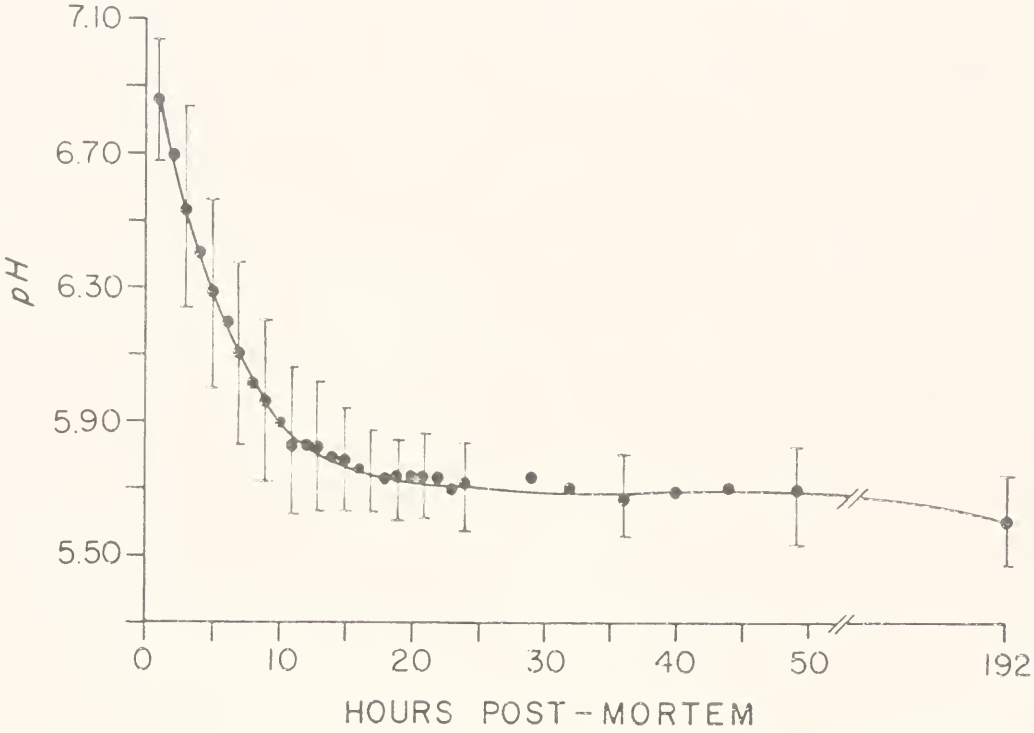

Fig. 7. Post-mortem changes in pH of L. dorsi muscle as presented by average values with standard deviations.

values at 24 and 48 hr post-mortem. This highly significant relationship might be explained by the very small change in pH values from 24 hr to 48 hr post-mortem as shown in Appendix Table 49. This result agrees with the work of Lewis et al. (1963), who found a correlation coefficient of .70 between pH values obtained at 24 and 48 hr post-mortem in pork L. dorsi muscle.

Table 5. Simple correlation coefficients between pH values of the L. dorsi at four post-mortem intervals.

	pH at:		
	24 hr	48 hr	192 hr
pH at 1 hr	.21	.24	.22
pH at 24 hr		.64**	.23
pH at 48 hr			.31

*$P_{<}.05 = .33$
**$P_{<}.01 = .42$

The relationship between pH and tenderness

Simple correlation coefficients between average pH and tenderness values obtained 1, 24, 48 and 192 hr post-mortem are presented in Table 6.

Correlations between pH of the L. dorsi taken 1 hr post-mortem and shear tenderness values of broiled and deep fat fried steaks, cooked at 1 hr post-mortem, were -.50 and -.65 respectively; these correlations were highly significant ($P_{<}.01$). Lower correlation values were obtained between the 1 hr pH value and panel tenderness scores of the steak cooked at 1 hr post-mortem.

Table 6. Simple correlation coefficients between tenderness and the pH of the L. dorsi and the rate of pH change during post-mortem.

Time post-mortem, hr	1				24			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
pH at 1 hr	-.50**	-.65**	.41*	.30	.28	.38*	-.43**	-.49**
pH at 24 hr					-.10	.04	-.13	-.11
pH at 48 hr								
pH at 192 hr								
Rate of pH change from 1 to 3 hr					-.15	-.07	.17	.13
Rate of pH change from 1 to 5 hr					-.30	-.26	.31	.30
Rate of pH change from 1 to 7 hr					-.20	-.19	.29	.27
Rate of pH change from 1 to 9 hr					-.34*	-.31	.38*	.40*
Rate of pH change from 1 to 11 hr					-.38*	-.42**	.50**	.48**

*P $<$ .05 = .33
**P $<$ .01 = .42

Table 6. (Cont.)

Time post-mortem, hr	48				192			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
pH at 1 hr	.20	.31	-.46**	-.39*	.30	.23	-.29	-.31
pH at 24 hr	.24	.14	-.19	-.38*	.43**	.50**	-.46**	-.55**
pH at 48 hr	.30	.38*	-.40*	-.55**	.54**	.46**	-.55**	-.60**
pH at 192 hr					.19	.17	-.33*	-.30
Rate of pH change from 1 to 3 hr	.05	.00	.32	.21	-.08	.02	.04	.16
Rate of pH change from 1 to 5 hr	-.09	-.19	.47**	.31	-.02	.08	-.00	.07
Rate of pH change from 1 to 7 hr	.00	-.11	.39*	.23	-.08	.04	.07	.12
Rate of pH change from 1 to 9 hr	-.12	-.24	.57**	.41*	-.27	-.09	.23	.22
Rate of pH change from 1 to 11 hr	-.15	-.30	.61**	.46**	-.26	-.10	.24	.23

*P < .05 = .33
**P < .01 = .42

However, the panel tenderness score of the broiled steaks was significantly ($P < .05$) correlated with the initial pH value, and the correlation approached the same level of significance for those steaks cooked by deep fat frying 1 hr post-mortem. These correlations clearly indicate that the higher the initial pH value the more tender the meat at 1 hr post-mortem.

Although it can be demonstrated that rigor may proceed without glycolysis, the drop in pH caused by the conversion of muscle glycogen to lactic acid may be used as an indication of rate of rigor development or as an indication of the severity and extent of rigor. In other words it may be assumed that a rapid rate of pH drop or a rapid rate of glycolysis from slaughter to 1 hr post-mortem is associated with either a rapid rate of rigor development or more severe rigor. Since initial pH was found by Bate-Smith and Bendall (1949), Briskey (1959), and Beecher et al. (1965) to depend on the severity of the death struggle, the results obtained in this study would lead to the theory that the more relaxed the animal was before or during death, the less rapid and less severe the rigor and the more tender the meat should be at 1 hr post-mortem. These relationships are explained by Davies' (1963) theory on muscle contraction and are in agreement with the report of Locker (1960 a) who found that the relaxed muscles were more tender than partly contracted muscles of beef.

The most striking phenomenon observed in the relationships between initial pH value and tenderness at the four post-mortem intervals was the difference in the direction of the signs of the correlations. Initial pH and tenderness of steaks cooked 24, 48 and 192 hr post-mortem were inversely related, which was contrary to the 1-hr post-mortem pH-tenderness relationship. Initial pH

was significantly ($P<.01$) correlated with the 24-hr panel tenderness values; correlations of -.43 and -.49 for broiled and deep fat fried steaks, respectively, were obtained. The correlation between initial pH and 24-hr shear tenderness was .38 ($P<.05$) for the deep fat fried steaks and approached that level of significance for the broiled steaks. The correlations between initial pH and 48-hr tenderness were significant only with panel tenderness. The relationships between initial pH and 192-hr tenderness were low but approached the 5 per cent level of significance.

The correlation coefficients showed no relationship between the 24-hr shear and panel tenderness values and pH value at that time. While a low relationship existed between the 24-hr pH value and the 48-hr tenderness value, the relationship between the same pH value and 192-hr tenderness value was highly ($P<.01$) significant.

The correlation coefficients between the 48-hr pH value and shear tenderness values at 48 hr were either approaching the 5 per cent level of significance (for broiled steaks) or significant at that level (for deep fat fried steaks). Higher relationships between the same pH and the 48-hr panel tenderness with correlations of -.40 and -.55 for the broiled and deep fat fried steaks, respectively, were obtained. These correlations were significant at the 5 per cent and one per cent levels of significance, respectively. The results agree essentially with work performed by Judge et al. (1960) who found significant negative correlation between panel tenderness and pH of pork loins. Correlation coefficients between the 48-hr pH value and 192-hr tenderness values were highly ($P<.01$) significant; higher pH values were associated with less tender steaks by both panel and shear tests.

Low correlation coefficients of .19 and .17 between final pH value and shear tenderness values at 192 hr for the broiled and deep fat fried steaks, respectively, were found. However, the correlations of -.33 and .30 between the same pH value and panel tenderness were significant ($P < .05$) for the broiled steaks and approached the same level of significance for the deep fat fried steaks. These data tend to agree with those reported by Husaini (1950a) who found no correlation between pH and tenderness at 14 days post-mortem. Walter et al. (1965) found negative correlations of -.230 and -.375 between W-B shear values and pH for the broiled and deep fat fried L. dorsi steaks at 5 days post-mortem; steaks with higher pH tended to be more tender. In this study, however, those correlations were positive, indicating that higher pH steaks tended to be less tender.

Generally, the correlation coefficients obtained between the rate of change in pH from 1 hr to 3, 5, 7, 9 and 11 hr post-mortem and tenderness values at 24, 48 and 192 hr post-mortem were either low or irregular. However, the most uniform and significant correlations were found between rate of pH change from 1 to 9 and from 1 to 11 hr post-mortem and tenderness values at 24 hr post-mortem. The correlations between the rate of pH changes and final tenderness were either low or approaching zero.

Temperature of the Longissimus dorsi during the chilling period

The curve in Fig. 8 shows the post-mortem time-temperature relationship. The curve represents the average temperature values of the 36 carcasses during the first 48 hr post-mortem. The graph illustrates that the internal temperature fall of the L. dorsi was slow for the first hour and very rapid

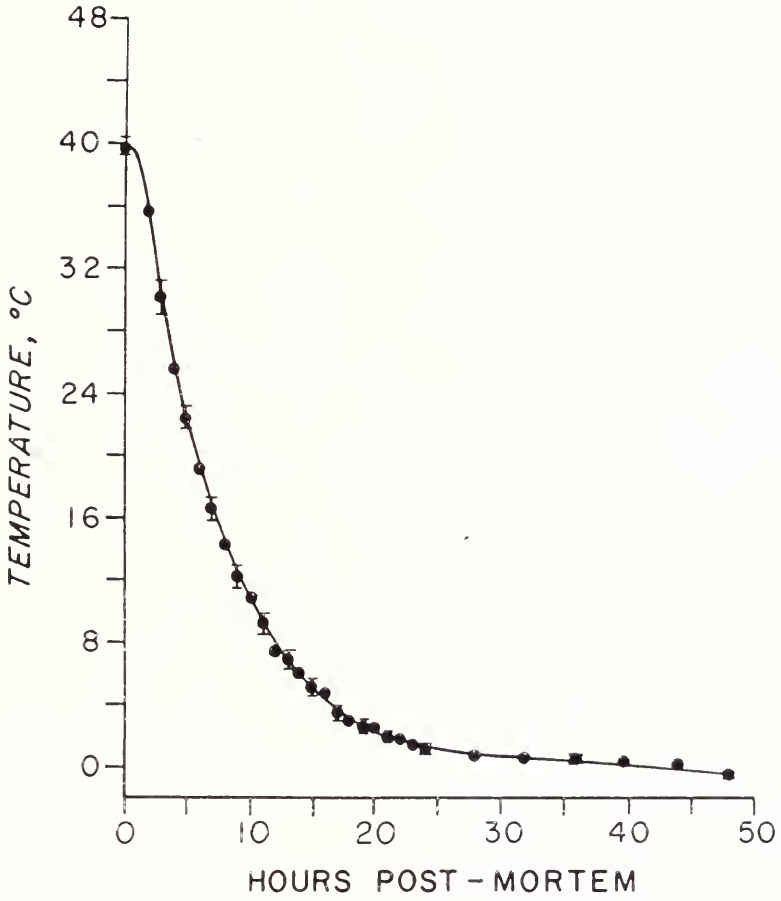

Fig. 8. Post-mortem changes in temperature of L. dorsi muscle as presented by average values with standard deviations.

thereafter for a period of approximately 20 hr post-mortem. Temperature change was slow after the 20th hr post-mortem, and the rate of chilling decreased with time until the internal L. dorsi temperature reached the chill room temperature of $0.0 \pm .6^{\circ}C$ at approximately 28 hr post-mortem.

The relationship between pH and rate of chilling of the Longissimus dorsi

A simple correlation coefficient analysis was used to study the relationships and/or the influence of temperature decline on pH change post-mortem; correlations are presented in Table 7.

At 1 hr post-mortem, a correlation coefficient of -.52 ($P < .01$) between temperature and pH was found; higher temperatures were associated with lower pH values and lower temperatures were associated with higher pH values. Since Forrest et al. (1965) reported correlations of .33 ($P < .05$) and .35 ($P < .05$) between muscle temperature at death and respiration and heart rate, respectively, immediately prior to death, and since heart and respiration rates are associated with blood and oxygen supplies to the muscle, it may be assumed that variations in initial muscle temperature are partially due to muscle activity preceding death and/or during the death struggle. Bate-Smith and Bendall (1949) found that the initial pH value of the muscle was the result of muscle activity immediately preceding death and/or of the death struggle. Beecher et al. (1965) found that the pH of the Semitendinosus was higher in pigs insensibilized by sodium pentobarbital injection (exhibited no death reaction) than in animals insensibilized with a captive-bolt pistol.

Average pH values at 24, 48 and 192 hr post-mortem were not related to the 1 hr temperature value. These data substantiate the observations of

Table 7. Simple correlation coefficients between post-mortem temperature and pH of the L. dorsi.

	pH at:				Rate of pH change from 1 hr to:				
	1 hr	24 hr	48 hr	192 hr	3 hr	5 hr	7 hr	9 hr	11 hr
Temperature at 1 hr	-.52**	-.07	.07	.00	-.56**	-.46**	-.41*	-.30	-.16
Rate of temperature change from 1 to 3 hr		.06	.37*	-.07	-.25	-.28	-.44**	-.47**	-.48**
Rate of temperature change from 1 to 5 hr		-.04	.23	-.10		-.34*	-.43**	-.52**	-.50**
Rate of temperature change from 1 to 7 hr		.03	.31	-.04			-.46**	-.55**	-.57**
Rate of temperature change from 1 to 9 hr		.03	.33*	-.03				-.56**	-.59**
Rate of temperature change from 1 to 11 hr		.04	.32	-.03					-.56**

*$P_{<}.05 = .33$
**$P_{<}.01 = .42$

Bate-Smith and Bendall (1949) and of Briskey (1959) that ultimate or post-rigor pH depends on the animal's state of fatigue and level of feeding prior to slaughter.

Correlations between L. dorsi temperature at 1 hr and the rate of pH change from 1 hr to 3, 5, 7, 9 and 11 hr were -.56 ($P_{<}.01$), -.46 ($P_{<}.01$), -.41 ($P_{<}.05$), -.30 and -.16, respectively.

This decrease in correlation could be explained by the fact that the variations between carcasses in rate of pH change decreased with increasing time post-mortem.

Average pH values at 24 and 192 hr post-mortem were independent of the rate of chilling. However, average pH values at 48 hr were significantly ($P_{<}.05$) related to the rate of chilling from 1 to 3 and from 1 to 9 hr post-mortem.

While the correlations between the rate of pH change from 1 to 3 and from 1 to 5 hr and rate of temperature change from 1 to 3 hr were low, all other correlations between pH and rates of temperature change were either significant ($P_{<}.05$) or highly significant ($P_{<}.01$). These negative correlations indicate that rate of pH change or rate of rigor development is inversely dependent on rate of chilling. These data are in agreement with the report of Beecher et al. (1965) who found that lowering the post-mortem holding temperature from 37 to 4°C slowed post-mortem glycolysis (retarded pH decline) in porcine Semitendinosus.

The relationship between tenderness and rate of chilling of the Longissimus dorsi post-mortem

A simple correlation coefficient analysis was used to investigate the relationship between tenderness and post-mortem change in temperature, as

an index of rate and extent of rigor development; results are shown in Table 8.

The correlation coefficients between L. dorsi temperature at 1 hr and tenderness values of the broiled steaks at 1 hr post-mortem were .54 and -.55 for shear and panel scores, respectively. The relationships were highly significant ($P_{<}.01$). Highly significant ($P_{<}.01$) correlations obtained between the 1-hr temperature and tenderness values of deep fat fried steaks were .65 and -.49 for shear and panel, respectively.

The correlation coefficients between the L. dorsi 1-hr temperature and tenderness values at 24, 48 and 192 hr post-mortem were low and insignificant.

The correlation coefficients between rate of temperature change from 1 to 3, 5, 7, 9 and 11 hr post-mortem and tenderness values at 24, 48 and 192 hr post-mortem were also low and of no significance.

According to these results, no direct relationship between tenderness and rate of chilling was found. This result was expected, since all carcasses were chilled under the same temperature. The significant correlations between the L. dorsi temperature and tenderness values at 1 hr post-mortem were explained previously by the significant relationship found between temperature and pH at 1 hr post-mortem.

Post-mortem changes in bound and free moisture of the Longissimus dorsi muscle

Average values for per cent total, bound and free moisture for the 144 raw L. dorsi steaks utilized at the four post-mortem intervals (36 steaks per interval) are graphically presented in Fig. 9. Also, shown in the same figure are average pH values at 1, 24, 48 and 192 hr post-mortem.

Table 8. Simple correlation coefficients between tenderness and rate of chilling of the L. dorsi post-mortem.

Time post-mortem, hr	1				24			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Temperature at 1 hr	.54**	.65**	-.55**	-.49**	-.04	-.02	-.01	.18
Rate of temperature change from 1 to 3 hr					.05	.10	-.13	-.12
Rate of temperature change from 1 to 5 hr					-.00	.05	-.07	-.16
Rate of temperature change from 1 to 7 hr					-.02	.09	-.21	-.21
Rate of temperature change from 1 to 9 hr					.07	.17	-.24	-.24
Rate of temperature change from 1 to 11 hr					.02	.06	-.16	-.20

*$P_{<}.05 = .33$
**$P_{<}.01 = .42$

Table 8 (Cont.)

Time post-mortem, hr	48				192			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Temperature at 1 hr	.07	-.00	-.11	-.14	.14	.11	-.15	-.18
Rate of temperature change from 1 to 3 hr	-.14	.01	-.18	-.05	.18	.01	-.11	-.19
Rate of temperature change from 1 to 5 hr	-.19	-.08	-.14	-.07	.14	.02	-.08	-.12
Rate of temperature change from 1 to 7 hr	-.12	.02	-.29	-.16	.21	.05	-.13	-.18
Rate of temperature change from 1 to 9 hr	-.03	.12	-.32	-.25	.25	.09	-.17	-.20
Rate of temperature change from 1 to 11 hr	-.08	.03	-.26	-.15	.17	.02	-.10	-.15

*$P_{<}.05 = .33$
**$P_{<}.01 = .42$

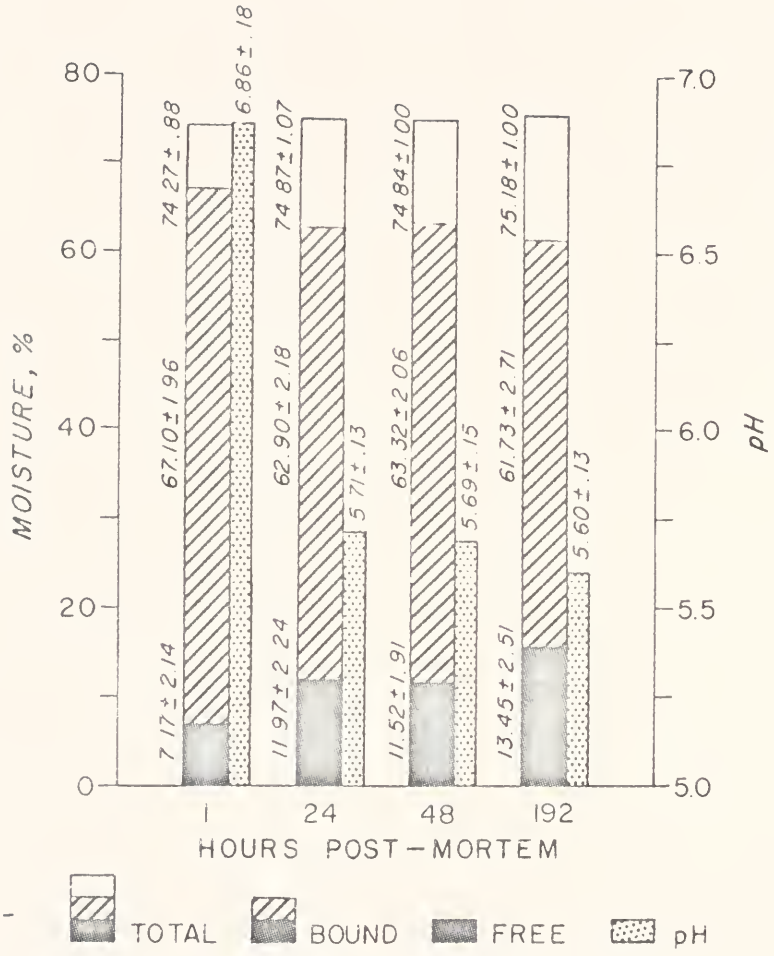

Fig. 9. Post-mortem changes in total, bound and free moisture of raw steaks from L. dorsi muscle.

Variations in per cent of total moisture among the four post-mortem intervals were very small. The average values of total moisture at 1, 24, 48 and 192 hr were, respectively, 74.27, 74.87, 74.84 and 75.18 per cent. The difference between average values was less than one per cent. Since the amount of free moisture was determined in this study as the difference between total and bound moisture values, the observation that variations between post-mortem intervals in the amount of total moisture were minute was important because post-mortem changes in free moisture was a primary objective of this study.

In general, bound moisture decreased with time post-mortem. The decrease in amount of bound moisture with time post-mortem was significant at the .005 level of probability. The highest average value (67.10 per cent) was observed at 1 hr post-mortem while the lowest value (61.73 per cent) was noticed at 192 hr post-mortem. An unexpected increase of .42 per cent in the amount of bound moisture was observed between 24 and 48 hr post-mortem. Average pH values at 24 and 48 hr were 5.71 and 5.69, respectively. This small increase in the amount of bound moisture may have been due either to experimental error or to some biochemical changes that caused an increase in net charge of muscle proteins (Hamm, 1963).

The trend in post-mortem change in amount of free moisture was opposite to that observed for the bound moisture. A marked increase in amount of free moisture from 7.17 per cent at 1 hr to 11.97 per cent at 24 hr was found. A rather slow change in amount of free moisture was observed after the 24th hr; a maximum average value of 13.45 per cent was found at 192 hr post-mortem. A small decrease in amount of free moisture (.45 per cent) was also observed

between the 24th and 48th hr. This decrease could be explained by the same factors discussed for the bound moisture. Here, also, post-mortem changes in amount of free moisture were significant at the .005 level of probability. These data are in agreement with that reported by Hashimoto et al. (1959) and Wierbicki and Deatherage (1958) who found that meat hydration dropped very markedly within a few hours after slaughter and reached a minimum in 24 to 48 hr; these data are contrary to the above two reports in that the increased hydration found with aging in those studies was not observed in this study. In fact, meat hydration was found to decrease with aging for 8 days. This observation was supported by the noticeable decrease in pH with aging; minimum pH values were obtained at 192 hr post-mortem.

The effect of pH and time post-mortem on free moisture of the Longissimus dorsi muscle

The effect of pH and time post-mortem on per cent free moisture of the L. dorsi muscle is shown by simple correlation and step-wise regression analysis. Table 9 presents the simple correlation coefficients obtained between these variables of pH and time using the 144 L. dorsi steaks removed at four post-mortem intervals.

Free moisture showed a significant ($P_{<}.01$) relationship to pH with a high correlation coefficient of -.73. This result is in line with the report of Hamm (1960) who found that the minimum hydration of meat was around pH 5.0. Also, this result supports the findings of Swift and Berman (1959), Judge et al. (1960), Kauffman et al. (1961) and Lewis et al. (1963) who found a high relationship between pH and free moisture.

Table 9. Simple correlation coefficients between time post-mortem, pH, free and bound moisture.[1/]

Independent variables	Time	pH
Free moisture, %	.53**	-.73**
Bound moisture, %	-.48**	
pH	-.55**	

[1/] Using values recorded at 1, 24, 48 and 192 hr post-mortem.

**$P_{<}.01 = .22$

Time post-mortem significantly ($P_{<}.01$) influenced the amount of free moisture in muscle, with a correlation coefficient of .53. This relationship was substantiated by the negative significant correlation of -.48 found between time post-mortem and bound moisture.

A negative significant ($P_{<}.01$) correlation of -.55 between pH and time post-mortem was found. This relationship could be explained by the fact that average pH values decreased with time post-mortem, with minimum average pH values at 192 hr post-mortem.

Simple and multiple correlations and regression coefficients for pH and time post-mortem influencing or related to muscle free moisture are presented in Table 10.

In this study muscle pH was responsible for 53.29% of the variability in per cent free moisture in the L. dorsi muscle and was the first variable entering the step-wise regression analysis. If the predictive value of per cent free moisture during 1 to 192 hr post-mortem was Y then the predictive equation

for Y from the knowledge of muscle pH at that particular time and during this specific (1 to 192 hr) post-mortem period becomes: Y = 36.93694 - 4.34375 (muscle pH). From the predictive equation, a .23 pH unit increase would decrease free moisture one per cent.

Table 10. Coefficients for predicting free moisture from pH and time post-mortem.[1/]

Independent variable	r XY	R	Constant	Partial regression coefficients b_1	b_2
pH	-.73**[a]	.73**[b]	36.93694	-4.34375	
Time	.53**[a]	.75**[c]	32.70938	-3.72526	.00813

[1/] Using values recorded at 1, 24, 48 and 192 hr post-mortem.

**[a] $P_{<}.01 = .22$

**[b] $P_{<}.01 = .22$

**[c] $P_{<}.01 = .25$

Time (1 to 192 hr) post-mortem had a significant simple correlation coefficient of .53 with per cent free moisture and accounted for 28.09% of the variability in the amount of free moisture in the muscle. When time post-mortem was combined with pH, the multiple correlation coefficient was increased from .73 to .75. This accounted for an additional 2.96% of the variation in free-moisture per cent, and the predictive equation was: Y = 32.70938 - 3.72526 (muscle pH) + .00813 (hr post-mortem). Holding pH constant, a one hour increase during the post-mortem period of 1 to 192 hr would increase free moisture content

.008 per cent. The addition of time, therefore, did not result in a significant increase in the estimate of per cent free moisture in the L. dorsi muscle.

The effect of pH, initial steak temperature, time post-mortem, free and bound moisture, cooking time and cooking method on cooking loss

Simple correlation coefficients between the most important factors influencing or associated with cooking loss as of 288 L. dorsi steaks are presented in Table 11. The relationship or the influence of pH, free moisture and cooking time on cooking losses are demonstrated in Figs. 10, 11 and 12, respectively.

Table 11. Simple correlation coefficients between cooking loss and pH, initial internal steak temperature, time post-mortem, free and bound moisture, cooking time and cooking method.

Independent variable	Cooking loss, %	Cooking time (Min/100 g wt.)
pH of L. dorsi at time of cooking	-.63**	-.54**
Initial internal steak temperature	-.63**	-.52**
Time post-mortem, hr	.52**	.46**
Free moisture, %	.46**	.51**
Bound moisture, %	-.43**	-----
Cooking time (Min/100 g wt.)	.40**	-----
Cooking method	.26**	-----

**$P_{<}.01 = .15$

The pH of the L. dorsi steaks at time of cooking was closely related to per cent cooking loss, with a highly significant ($P_{<}.01$) correlation coefficient

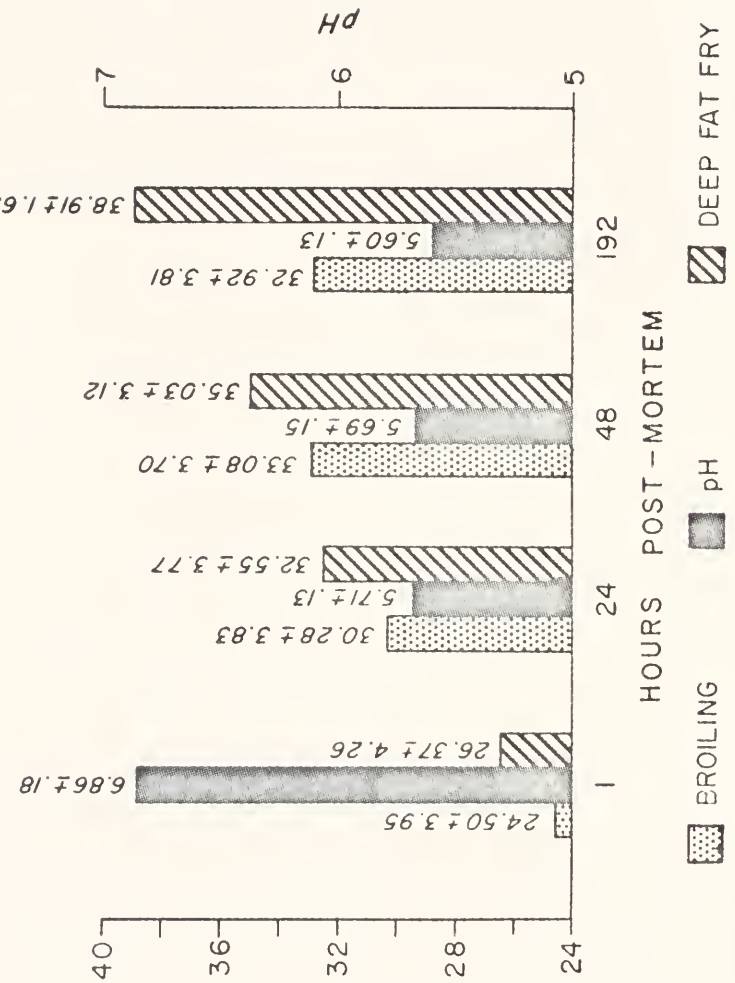

Fig. 10. Post-mortem changes in cooking losses and pH.

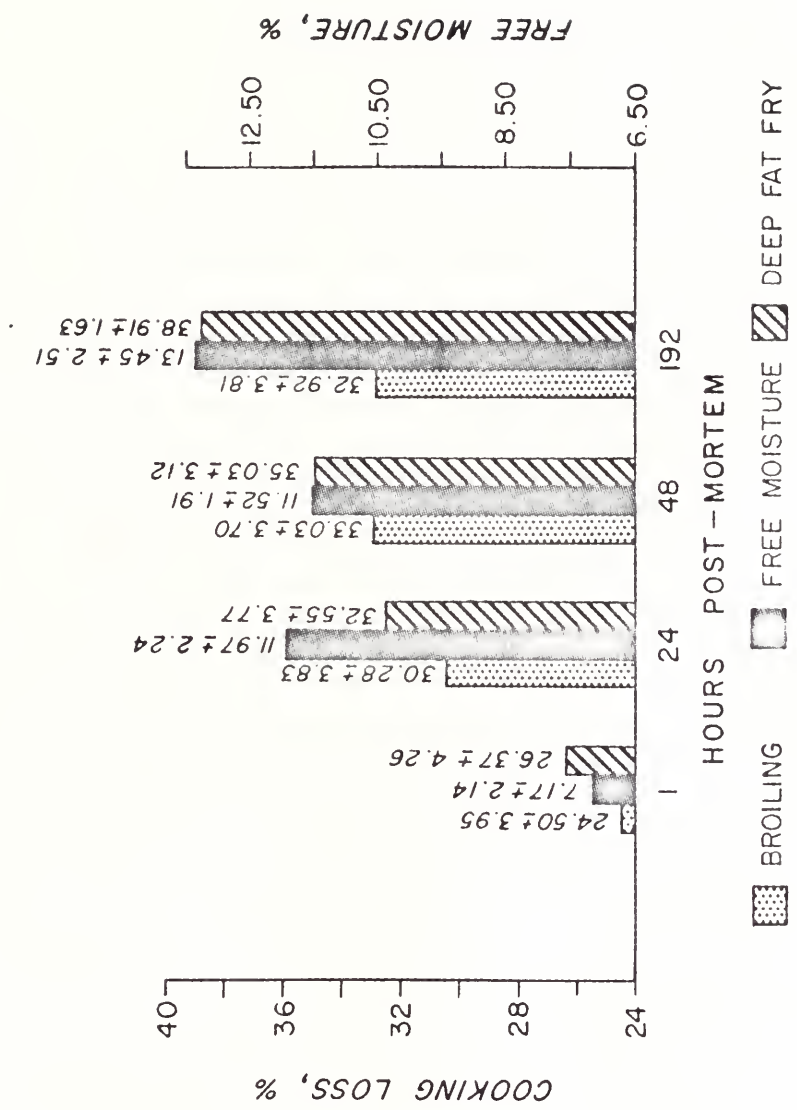

Fig. 11. Post-mortem changes in cooking losses and free moisture.

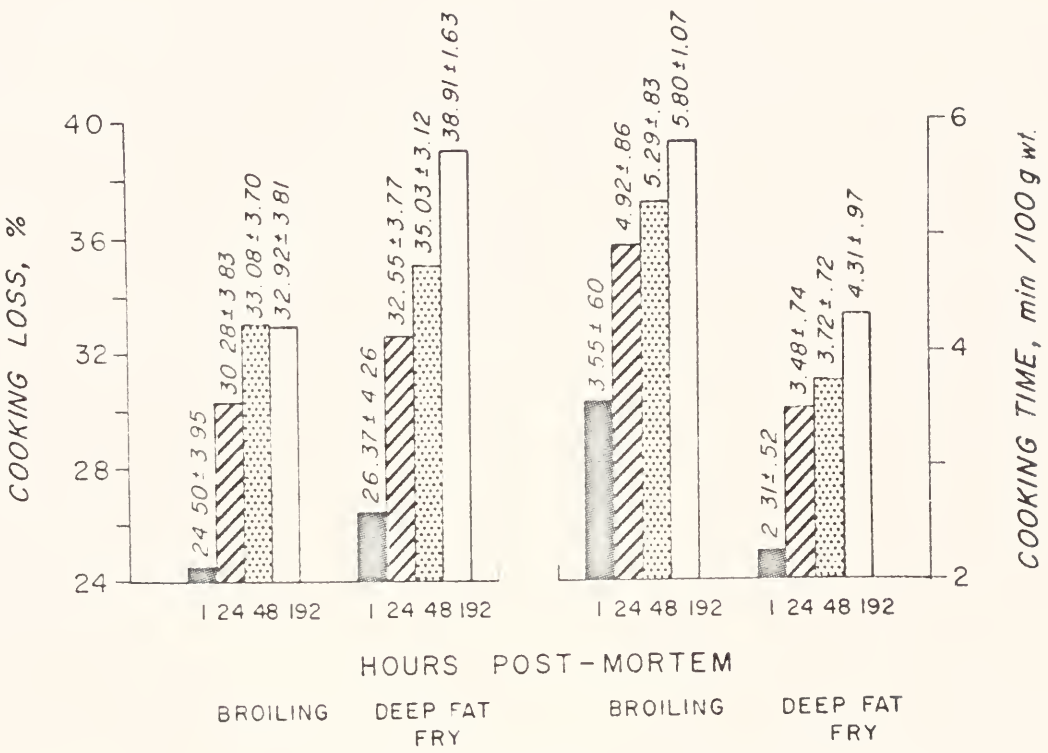

Fig. 12. Post-mortem changes in cooking losses and cooking time.

of -.63. This result substantiates the observations of Hamm and Deatherage (1960) who found that the pH of fresh meat markedly influenced water-holding capacity of cooked meat. Also, this result supports the report of Kauffman et al. (1961) who found that curing and cooking shrinkage was lower in pork muscle with high pH values.

The pH of the L. dorsi steaks at time of cooking and cooking time (Min/100 g wt.) were negatively and significantly ($P_{<}.01$) related with a correlation coefficient of -.54.

Correlation coefficients between initial internal steak temperature and cooking loss and cooking time were -.63 and -.52, respectively; both correlations were highly significant ($P_{<}.01$).

Time post-mortem showed significant ($P_{<}.01$) relationships with cooking loss and cooking time, with correlation coefficients of .52 and .46, respectively.

Per cent cooking loss was significantly ($P_{<}.01$) related to free and bound moisture, with correlations of .46 and .43, respectively. A significant ($P_{<}.01$) correlation of .51 between free moisture and cooking time was found.

Cooking loss was also influenced by the cooking method; this was demonstrated by the significant ($P_{<}.01$) correlation of .26 found between cooking method and per cent cooking loss; though significant, the correlation was low. These data are in agreement with those reported by Paul et al. (1952).

Simple and multiple correlations and regression coefficients for factors influencing and/or associated with cooking loss are presented in Table 12.

In this study pH of the L. dorsi at time of cooking was associated with 39.69% of the variability in per cent cooking loss and was the first variable entering the step-wise regression analysis. The partial regression coefficient for

Table 12. Coefficients for the most important factors influencing and/or associated with cooking loss.

Independent variable	r_{XY}	R	Constant	Partial Regression Coefficients				
				b_1	b_2	b_3	b_4	b_5
pH of L. dorsi at time of cooking	-.63**	.63	72.59319	-6.84922				
Cooking method	.26**	.68	72.59325	-6.84923	1.51051			
Cooking time (Min/100 g wt.)	.40**	.74	47.09673	-4.03065	3.00260	2.07676		
Time post-mortem, hr	.52**	.75	43.94033	-3.45319	2.81630	1.81746	.01195	
Initial internal steak temperature	-.63**	.76	30.31647	-5.53560	2.48491	1.47559	.01773	-.17033

**$P_{<}.01 = .15$

the relationship of pH and cooking loss indicated that pH would have to be decreased .5 unit to increase cooking loss by 3.43%. When cooking method was added to the equation, an increase in accountable variability of 6.55% was noted. The addition of cooking time in the analysis accounted for an additional 8.52% of the variability in estimating per cent cooking loss. Finally, the addition of time post-mortem and internal steak temperature to the equation would account for an additional 3 per cent of the variability, which is quite low.

Post-mortem changes in juiciness of the Longissimus dorsi steaks

Mean values of panel juiciness scores for the broiled and deep fat fried steaks are presented in Table 13. Statistical analysis (Table 14) of the taste panel scores showed that the differences in juiciness between the four treatment groups were not significant. Average post-mortem changes in juiciness scores for the 36 animals used are shown graphically in Fig. 13.

Differences in average juiciness scores between the 1, 24, 48 and 192-hr post-mortem time were significant at the .005 level of probability. Average juiciness scores at the four post-mortem intervals were higher for the broiled than for the deep fat fried steaks. This observation was statistically significant at the .01 level of significance. However, the time post-mortem X cooking method interaction was insignificant.

The relationship between juiciness and bound moisture, cooking loss, cooking method and time post-mortem

The relationships between average panel juiciness scores, for the 288 broiled and deep fat fried L. dorsi steaks, and factors that had been reported

Table 13. Mean values of panel juiciness scores of the L. dorsi steaks.[1/]

Time post-mortem, hr	1		24		48		192	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Treatment No.								
1	4.99	4.82	6.11	5.67	5.72	5.17	5.07	4.89
2	5.07	4.58	5.74	5.80	5.25	5.14	5.40	4.98
3	4.75	4.75	5.97	5.50	5.06	4.75	4.98	4.84
4	4.79	4.67	5.36	5.56	5.64	5.33	4.94	4.74
Over-all mean	4.90	4.71	5.80	5.63	5.42	5.10	5.10	4.86
Std. deviation	.35	.45	.73	.68	.70	.61	.61	.58
Std. error of mean	.06	.08	.12	.11	.12	.10	.10	.10

Std. error of time and method mean, SX = ± .1

[1/] See Appendix Table 45 for juiciness scale.

Table 14. Analysis of variance for panel juiciness scores of the L. dorsi steaks.

Source of variation	d.f.[1/]	Sum of squares	Mean square	F-values	Significance of difference
Time	3	33.86	11.29	112.90	.005
Method	1	3.62	3.62	17.71*	.01
Time X method	3	.25	.08	.80	N.S.
Treatment	3	2.33	.78	.98*	N.S.
Treatment X time	9	4.81	.53	.93	N.S.
Method X treatment	3	.54	.18	.72*	N.S.
Method X time X treatment	9	2.32	.26	2.60	.05
Animals/treatment	32	27.05	.85	1.49	.1
Time X animals/treatment	96	55.20	.57	5.70	.005
Method X animals/treatment	32	4.18	.13	1.3	N.S.
Time X method X animals/treatment	96	9.76	.10		
Total	287				

d.f.[1/] For testing methods, treatments and method X treatment were estimated according to Satterthwaite (1946).

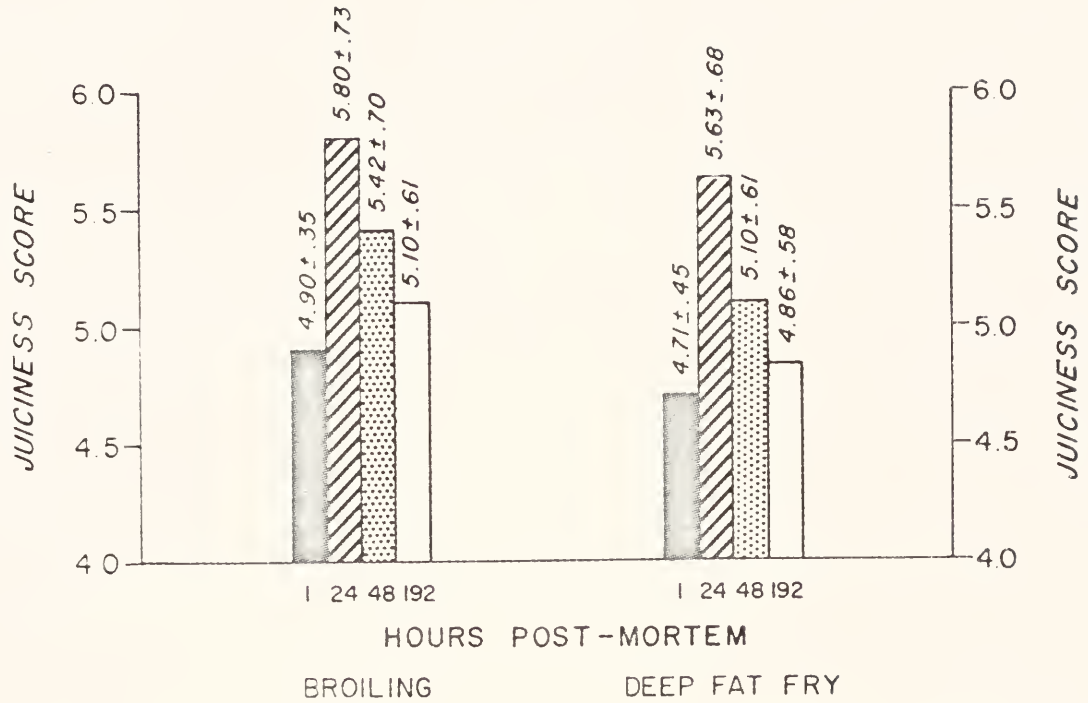

Fig.13. Post-mortem changes in juiciness of L. dorsi steaks cooked by broiling and deep fat frying.

to influence and/or to be associated with juiciness, are presented in Table 15.

Table 15. Simple correlation coefficients between juiciness and bound moisture, cooking loss, cooking method and time post-mortem.

	Juiciness
Bound moisture, %	-.26**
Cooking loss, %	-.16**
Cooking method	-.16**
Time	-.11

*$P_{<}.01 = .15$
**$P_{<}.05 = .12$

The simple correlation between average juiciness scores and bound moisture of -.26 was highly significant ($P_{<}.01$) indicating a definite relationship with juiciness. This result substantiates Hamm (1960) who reported that bound water may be related to juiciness of meat. Also, this finding agrees with that of Hardy and Noble (1945), who found a highly significant correlation between percentage of press fluid and juiciness scores of pork loin roasts. Also, Gaddis et al. (1950) and Ritchey and Hostetler (1964) found low correlation coefficients between subjective scores for juiciness and either free or bound water. However, this result is in contrast to the report of Ritchey (1965) who found no significant correlation between subjective scores for eating quality in two beef muscles and either bound or free water.

A low, but significant ($P_{<}.01$) correlation of -.16 between average juiciness scores and cooking loss was found.

The simple correlation between juiciness and cooking method of -.16 was low but highly significant ($P_{<}.01$) indicating that cooking method had some effect on juiciness.

Even though the differences in average juiciness scores between the four post-mortem times were significant, time post-mortem was found to have no significant relationship with juiciness, with a low negative correlation of -.11.

Simple and multiple correlations and partial regression coefficients for the most important factors influencing or associated with average juiciness scores are presented in Table 16.

Bound moisture was the first variable entered and accounted for 6.76 per cent of the variability in juiciness. A one-unit increase in juiciness score would require 6.24 per cent increase in bound moisture. When cooking loss was combined with bound moisture in the step-wise regression analysis, the multiple correlation coefficient was increased from .26 to .40. This accounts for an additional 9.24 per cent of the variation in juiciness scores. When time post-mortem and cooking method were combined with bound moisture and cooking loss in the step-wise regression analysis, the multiple correlation coefficient was increased from .40 to .45. The final coefficient of .45 would account for 20.25 per cent of the variability in juiciness.

Post-mortem changes in flavor of the Longissimus dorsi steaks

Mean values and analysis of variance for panel flavor scores are presented in Tables 17 and 18, respectively. Analysis of variance revealed that treatment had no significant effect on the average flavor scores. Therefore, the flavor data obtained from the 36 animals were considered as one group. Figure 14 graphically

Table 16. Coefficients for the most important factors influencing and/or associated with juiciness of the L. dorsi steaks.

Independent variable	r_{XY}	R	Constant	Partial Regression Coefficients b_1	b_2	b_3	b_4
Bound moisture, %	-.26	.26	9.16695	-6.23729			
Cooking loss, %	-.16	.40	12.62115	-.09632	-.04068		
Time post-mortem, hr	-.11	.43	13.41882	-.11158	-.03107	-.00195	
Cooking method	-.16	.45	13.14784	-.10949	-.02642	-.00210	-.07222

Table 17. Mean values of panel flavor scores of the L. dorsi steaks.[1/]

Post-mortem time, hr	1		24		48		192	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Treatment No.								
1	4.60	4.44	5.28	5.14	5.42	5.22	5.80	5.63
2	4.04	3.88	5.39	5.29	5.19	5.36	5.95	5.80
3	4.15	3.99	5.56	5.08	5.39	5.25	6.00	5.97
4	4.29	4.10	5.22	5.15	5.25	5.00	5.88	5.50
Over-all mean	4.27	4.10	5.36	5.17	5.31	5.21	5.91	5.73
Std. deviation	.74	.73	.51	.40	.44	.46	.17	.17
Std. error of mean	.12	.12	.09	.07	.07	.08	.03	.03

Std. error of time and method mean, SX = ± .09

[1/] See Appendix Table 45 for flavor scale.

Table 18. Analysis of variance for panel flavor scores of the L. dorsi steaks.

Source of variation	d.f.[1/]	Sum of squares	Mean square	F-values	Significance of difference
Time	3	101.04	33.68	421.00	.005
Method	1	1.96	1.96	18.55*	.005
Time X method	3	.10	.03	.38	N.S.
Treatment	3	.92	.31	.78*	N.S.
Treatment X time	9	4.23	.47	.90	N.S.
Method X treatment	3	.28	.09	.94*	N.S.
Method X time X treatment	9	.91	.10	1.25	N.S.
Animals/treatment	32	19.03	.59	1.13	N.S.
Time X animals/treatment	96	50.39	.52	6.50	.005
Method X animals/treatment	32	2.67	.08	1.00	N.S.
Time X method X animals/treatment	96	7.81	.08		
Total	287				

d.f.[1/] For testing methods, treatments and method X treatment were estimated according to Satterthwaite (1946).

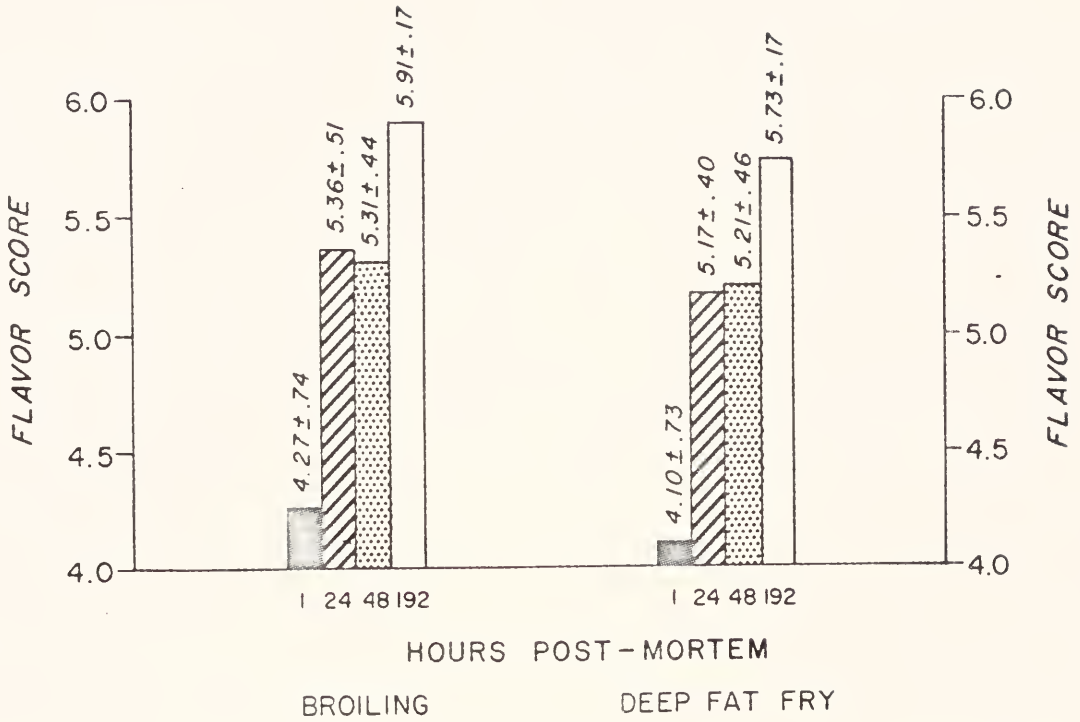

Fig. 14. Post-mortem changes in flavor of L. dorsi steaks cooked by broiling and deep fat frying.

represents average post-mortem changes in flavor scores.

Average taste panel scores indicated that time post-mortem had a marked influence on the flavor of the steaks tested and that panel members preferred the flavor of the steaks aged 8 days slightly more than those at 24 or 48 hr and markedly more than the 1-hr steaks. These observations were statistically substantiated with and F-value significant at the .005 level of probability.

Cooking methods were found to have significant ($P_{<}.005$) effect on flavor scores. Average flavor scores indicated that panel members preferred the flavor of the broiled steaks more than the deep fat fried, this finding held true at each of the four post-mortem intervals. Although, the preference by the panel members for the flavor of broiled steak was statistically significant, the difference between mean flavor values at 192 hr was small, 0.18.

The effect of time post-mortem on the flavor of the broiled and deep fat fried *Longissimus dorsi* steaks

Simple and multiple correlations and regression coefficients between time (1 to 192 hr) post-mortem and flavor scores of the broiled and deep fat fried steaks are presented in Table 19. Highly significant ($P_{<}.01$) correlation coefficients of .58 and .59 between time post-mortem and flavor scores of the broiled and deep fat fried steaks, respectively, were found. During the 1 to 192 hr post-mortem period used in this study, time was responsible for 33.64% and 38.81% of the variability in the flavor of the broiled and deep fat fried steaks, respectively. If the predicted value of flavor for the broiled steaks between 1 to 192 hr post-mortem was Y than the predictive equation for Y from the knowledge of time post-mortem becomes: $Y = 4.79153 + .00640$ (hr post-mortem). From the equation, a period

of 79.13 hr post-mortem would increase the flavor score by .5 unit over that flavor obtained 1 hr post-mortem. The predictive equation for Y for the deep fat fried steaks was: Y = 4.63524 + .00626 (hr post-mortem). From the equation, a period of 79.87 hr post-mortem would increase the flavor score by .5 unit over that obtained 1 hr post-mortem. The correlations and regression equations obtained indicated that the flavor of both broiled and deep fat fried steaks improved with time post-mortem.

Table 19. Coefficient for predicting the flavor of broiled and deep fat fried L. dorsi steaks from time post-mortem.

Cooking method	Independent variable	r XY	R	Constant	Partial regression coefficient b_1
Broiled	Time	.58**[a]	.58**[b]	4.79153	.00640
Deep fat fried	Time	.59**[a]	.59**[b]	4.63524	.00626

**[a] $P_{<}$ .01 = .22
**[b] $P_{<}$ .01 = .22

Post-mortem changes in tenderness of the Longissimus dorsi steaks

Average shear force and panel tenderness values are shown in Tables 20 and 21, respectively. The analysis of variance shown in Tables 22 and 23 for the shear and panel tenderness, respectively, revealed no significant difference due to treatment based on the above fact, the 36 animals were considered as one group and the overall means, plotted graphically in Fig. 15 will be considered in the following discussion.

Table 20. Mean values of W-B shear force values of the L. dorsi steaks.[1/]

Time post-mortem, hr	1		24		48		192	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Treatment No.								
1	5.78	5.46	8.19	7.61	6.58	6.85	4.33	4.36
2	5.35	5.33	8.71	8.57	7.91	7.53	5.02	4.73
3	5.60	5.36	8.57	8.13	7.40	7.48	5.07	5.00
4	6.18	6.23	8.64	7.62	8.17	7.60	5.45	5.74
Over-all mean	5.73	5.60	8.53	7.98	7.52	7.37	4.97	4.96
Std. deviation	1.30	1.43	1.74	1.48	1.47	1.22	1.54	1.67
Std. error of mean	.22	.24	.29	.25	.25	.20	.26	.28
Std. error of time and method mean, SX = ± .26								

[1/] Expressed as kg required to shear a 1.27 - cm. core.

Table 22. Analysis of variance for W-B shear force values of the L. dorsi steaks.

Source of variation	d.f.[1/]	Sum of squares	Mean square	F-values	Significance of difference
Time post-mortem	3	504.52	168.17	420.43	.005
Method of cooking	1	3.12	3.12	2.51*	N.S.
Time X method	3	2.89	.96	2.40	.1
Treatment	3	24.18	8.06	1.39*	N.S.
Treatment X time	9	17.93	1.99	.59	N.S.
Method X treatment	3	.28	.09	.51*	N.S.
Method X time X treatment	9	4.78	.53	1.33	N.S.
Animals/treatment	32	198.89	6.22	1.85	.025
Time X animals/treatment	96	323.53	3.37	8.43	.005
Method X animals/treatment	32	14.23	.44	1.10	N.S.
Time X method X animals/treatment	96	38.16	.40		
Total	287	1132.50	3.95		

d.f.[1/] For testing methods, treatments and method X treatment are estimated according to Satterthwaite (1946).

Table 21. Mean values of panel tenderness scores of the L. dorsi steaks.[1/]

Time, post-mortem, hr	1		24		48		192	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Treatment No.								
1	5.42	5.75	3.11	3.58	4.19	4.47	6.74	6.65
2	5.78	5.78	2.83	3.10	3.89	4.19	6.29	6.67
3	5.39	5.64	3.00	3.03	3.78	4.17	6.30	6.71
4	5.39	5.47	3.44	3.68	4.14	4.39	6.05	5.85
Over-all mean	5.49	5.66	3.10	3.35	4.00	4.31	6.34	6.47
Std. deviation	.98	.93	1.26	1.29	1.27	1.24	1.00	1.05
Std. error of mean	.16	.15	.21	.22	.21	.21	.17	.18
Std. error of time and method mean, SX = ± .20								

[1/] See Appendix Table 45 for tenderness scale.

Table 23. Analysis of variance for panel tenderness scores of the L. dorsi steaks.

Source of variation	d.f.[1/]	Sum of squares	Mean square	F-values	Significance of difference
Time	3	438.10	146.03	859.00	.005
Method	1	3.25	3.25	10.69*	.05
Time X method	3	.35	.12	.71	N.S.
Treatment	3	2.32	.77	.38*	N.S.
Treatment X time	9	10.33	1.15	.70	N.S.
Method X treatment	3	.35	.12	.73*	N.S.
Method X time X treatment	9	1.81	.20	1.18	N.S.
Animals/treatment	32	165.14	5.16	3.13	.005
Time X animals/treatment	96	157.99	1.65	9.71	.005
Method X animals/treatment	32	6.34	.20	1.17	N.S.
Time X method X animals/treatment	96	16.43	.17		
Total	287				

d.f.[1/] For testing method, treatments and method X treatment were estimated according to Satterthwaite (1946).

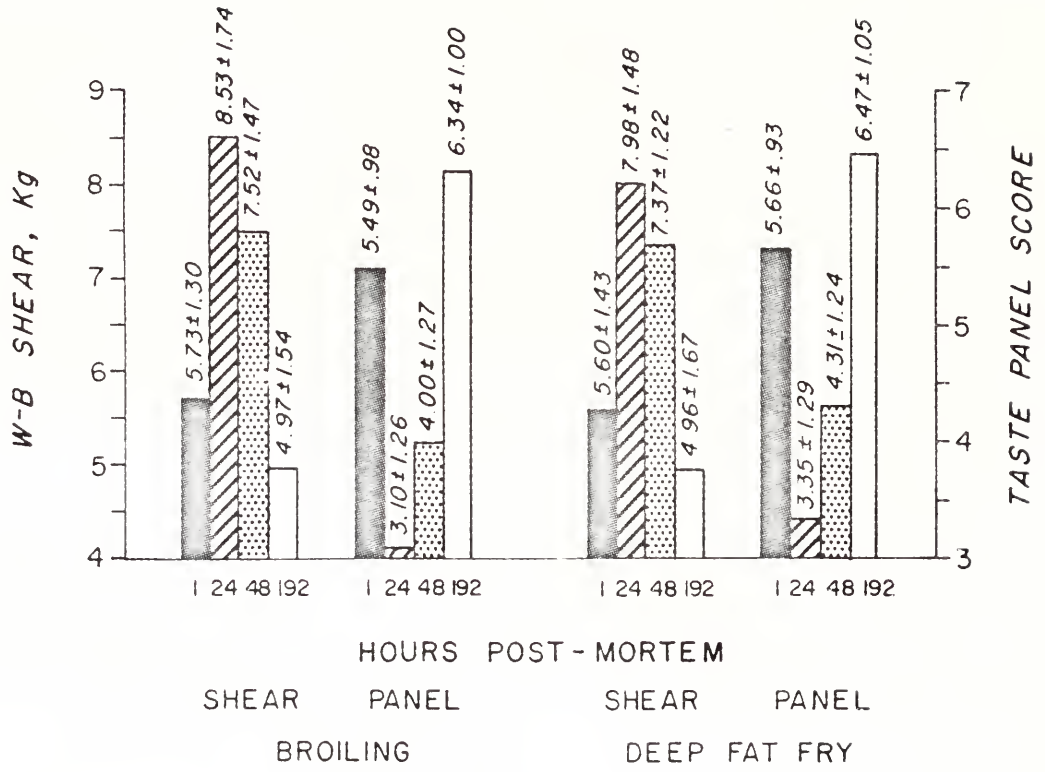

Fig.15. Post-mortom changes in tenderness of L. dorsi steaks cooked by broiling and deep fat frying.

The relationships between subjective and objective methods of evaluating tenderness are shown in Table 24. Panel tenderness scores were significantly ($P_{<}.01$) correlated with shear tenderness values at the four post-mortem periods studied. Strikingly high correlation coefficients of -.93 and -.84 between panel tenderness and shear tenderness for steaks cooked by broiling and deep fat frying, respectively, were observed at 192 hr post-mortem.

Table 24. Simple correlation coefficients between tenderness values obtained by taste panel and W-B shear at four post-mortem intervals.

Time post-mortem, hr	Variables	Cooking method	
		Broiling	Deep fat fry
1	Panel X shear	-.71**	-.66**
24	Panel X shear	-.59**	-.76**
48	Panel X shear	-.66**	-.77**
192	Panel X shear	-.93**	-.84**

**$P_{<}.01 = .42$

The subjective and objective evaluation of tenderness demonstrated that the L. dorsi steaks were tender at 1 hr post-mortem, least tender at 24 hr and became progressively more tender with increased time post-mortem, with maximum tenderness values obtained at 192 hr post-mortem. Differences between average tenderness values at 1, 24, 48 and 192 hr post-mortem were statistically significant ($P_{<}.005$). These data agree with those reported by Ramsbottom and Strandine (1949) and are in contrast to those of Goll et al. (1964) who reported that the

Semitendinosus muscle was least tender immediately after death and became progressively more tender with post-mortem time.

Analysis of variance revealed that method of cooking had no effect on shear tenderness. However, cooking methods showed a significant ($P_{<}.005$) effect on panel scores and in favor of the deep fat fried steaks compared to the broiled. This result does not agree with the recent report of Walter et al. (1965) that the broiled steaks were more tender than the deep fat fried L. dorsi steaks. In the Walter et al. (1965) study, however, W-B shear was used in evaluating tenderness.

The relationship between 1, 24, 48 and 192 hr post-mortem tenderness

Simple correlation coefficients between average tenderness values at 1, 24, 48 and 192 hr post-mortem are presented in Table 25.

The 24-hr shear tenderness values of broiled and deep fat fried steaks were negatively but not significantly correlated with the 1-hr shear tenderness values with correlations of -.14 and -.25, respectively. However, panel tenderness at 24 hr showed no relationship to panel values at 1 hr post-mortem. Similar relationships were found between 48 hr and 1 hr tenderness values. While correlations between 192 hr and 1 hr panel tenderness scores approached zero, a negative significant ($P_{<}.05$) correlation of -.33 was found between scores at those periods when tenderness was evaluated by the shear and when the steaks were cooked by broiling. However, for the same periods and for steaks cooked by deep fat frying, a lower, negative, insignificant correlation of -.23 was found between shear tenderness values.

Table 25. Simple correlation coefficients between 1, 24, 48 and 192 hr post-mortem tenderness.

Time post-mortem, hr	1				24				48			
Tenderness evaluation	Shear		Panel		Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF	Br	DF	Br	DF
Panel at 24 hr	---	---	-.01	-.01								
Shear at 24 hr	-.14	-.25	---	---								
Panel at 48 hr	---	---	.02	.09	---	---	.81**	.62**				
Shear at 48 hr	-.25	-.20	---	---	.61**	.67**	---	---				
Panel at 192 hr	---	---	-.04	.02	---	---	.44**	.20	---	---	.64**	.61**
Shear at 192 hr	-.33*	-.23	---	---	.38*	.40*	---	---	.63**	.66**	---	---

*$P_{<}.05 = .33$
**$P_{<}.01 = .42$

Correlation coefficients between shear tenderness values at 48 and 24 hr post-mortem were .61 and .67 for the broiled and deep fat fried steaks, respectively. For the same periods and for panel tenderness, the correlations of .81 and .62 for the broiled and deep fat fried steaks, respectively, were obtained. All correlations between tenderness values at 48 and 24 hr post-mortem were highly ($P_{<}.01$) significant. Shear tenderness values at 192 hr were significantly ($P_{<}.05$) related to the 24 hr values with correlations of .38 and .40 for the broiled and deep fat fried steaks, respectively. The relationship between panel tenderness scores for the same periods, however, were different. While a significant ($P_{<}.01$) correlation of .44 between panel tenderness scores for steaks cooked by broiling was found, a low, insignificant correlation of .20 was found for those steaks cooked by deep fat frying.

The most uniform correlations were noticed between the 192-hr and 48-hr tenderness values. For the shear values these correlations were .63 and .66 for the broiled and deep fat fried steaks, respectively. Similar correlations of .64 and .61 for the broiled and deep fat fried steaks, respectively, were obtained with the panel scores. All correlations indicate that tenderness values at 192 hr were highly dependent on the 48-hr values and to a lesser extent on the 24-hr tenderness values. Final tenderness values appeared to be inversely related to initial tenderness values at 1 hr post-mortem. The above post-mortem tenderness relationships were also confirmed by the following observations. The 36 animals were ranked on the basis of 1-hr post-mortem W-B shear values of the broiled L. dorsi steaks. The animals were then divided into two groups: 1 through 18 represented the "tough" group while 19 through 36 represented the

"tender" group. Average shear values for the "tough" and "tender" groups were then calculated at each of the four post-mortem intervals studied. Average panel tenderness values for the two groups were also calculated at each of the post-mortem times. Again, the 36 animals were ranked according to W-B shear values at 24, 48 and 192 hr post-mortem, and the same procedures discussed above were followed. The results are demonstrated in Figs. 16 through 19, respectively, for the 1, 24, 48 and 192-hr rankings.

According to the 1-hr ranking, the average shear value found for the "tough" group was 6.73, compared to 4.73 for the "tender" group. However, final average shear values were 4.60 and 5.34, respectively, for the "tough" and "tender" groups. The most interesting observation noticed in Fig. 16 was the fact that final average shear values were dependent upon the average shear values at 24 and 48 hr and were independent on initial values. All the above observations were also true when tenderness was evaluated by the panel members.

Fig. 17 demonstrates the results obtained from ranking based on average shear values at 24 hr post-mortem. The "tough" group at 24 hr was relatively less tender at 48 and 192 hr than the 24 hr "tender" group. The same results were obtained when tenderness was subjectively evaluated.

The dependence of final tenderness at 192 hr on tenderness values at 48 hr is clearly demonstrated in Fig. 18. The average shear values for the "tough" and "tender" groups at 48 hr were, respectively, 8.68 and 6.35 kg. At 192 hr average shear values were 6.01 and 3.93, respectively, for the "tough" and "tender" groups. The difference between the "tough" and "tender" groups were 2.67 and 2.42 kg, respectively, at 48 and 192 hr post-mortem.

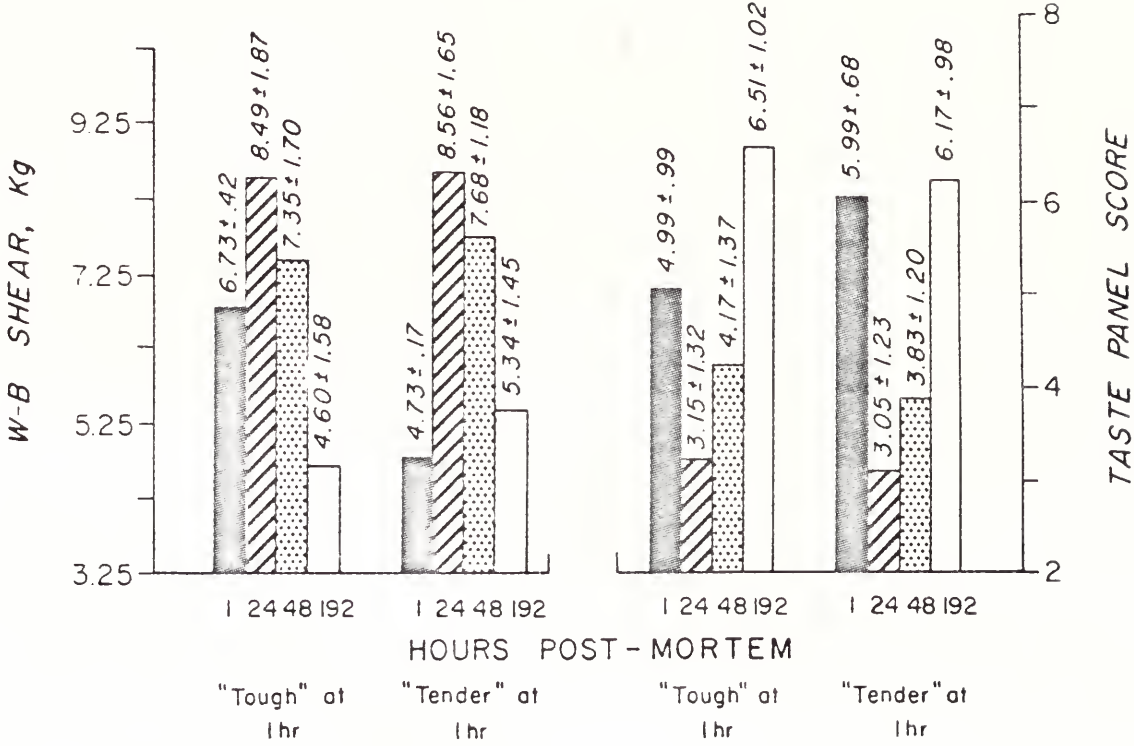

Fig.16. Average tenderness changes for the "tough" and "tender" groups based on 1 hr shear ranking.

Fig.17. Average tenderness changes for the "tough" and "tender" groups based on 24 hr shear ranking.

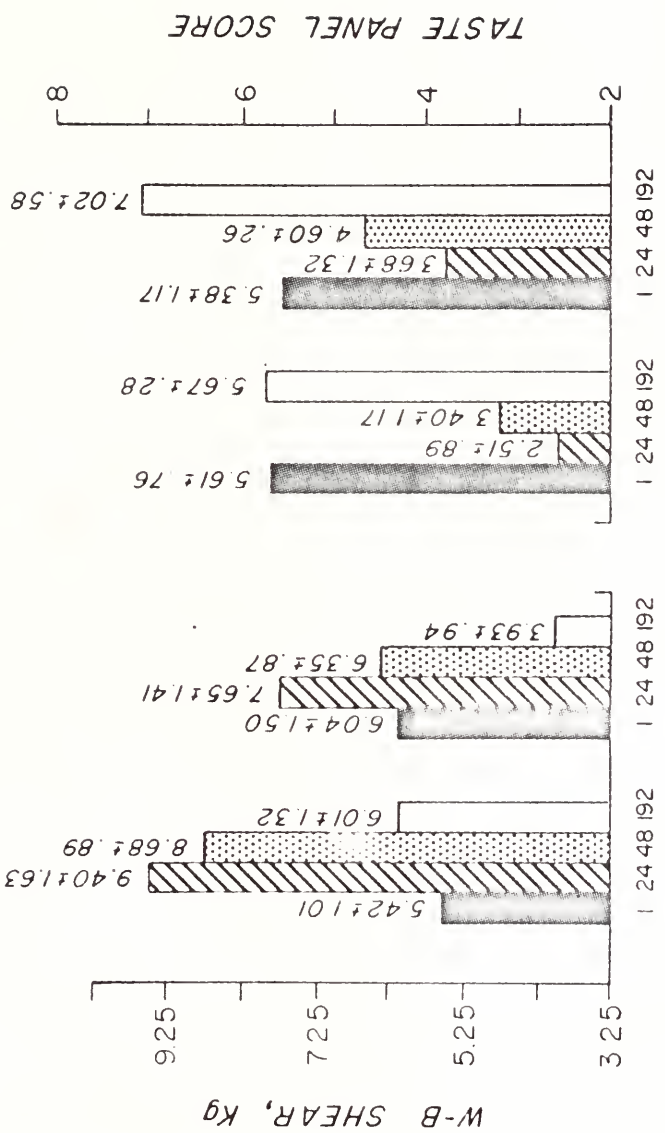

Fig. 18. Average tenderness changes for the "tough" and "tender" groups based on 48 hr shear ranking.

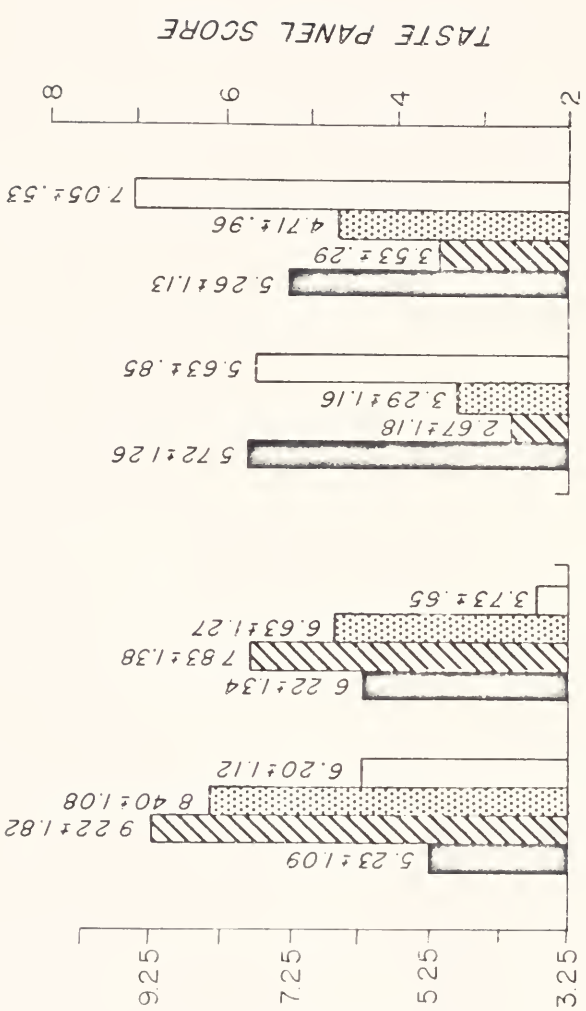

Fig. 19. Average tenderness changes for the "tough" and "tender" groups based on 192 hr shear ranking.

Fig. 19 demonstrates the results obtained when the ranking was based on the average shear values at 192 hr post-mortem. The difference between the "tough" and "tender" groups were 2.47, 1.77 and 1.39 kg, for the 192, 48 and 24 hr, respectively. These results substantiated the previous results obtained from the ranking at 1, 24 and 48 hr and clearly indicated that final tenderness was highly dependent on the 48-hr and to a less extent on the 24-hr tenderness values. The same figure also demonstrates that final tenderness was inversely related to initial tenderness at 1 hr post-mortem.

These results verify the observations of Huffman (1962) who reported that animals stressed before slaughtering produced more tender meat than the unstressed group (see the relationships between tenderness, pH and temperature). Furthermore, these data would indicate that final tenderness at 192 hr post-mortem was dependent on the chemical and physical changes that occurred in the muscle during the first 48 hr post-mortem. These data also tend to support the report of Husaini et al. (1950b) who found a correlation of .54 between tenderness at 3 and 15 days post-mortem.

Table 26 presents the simple and multiple correlation coefficients for the most important time post-mortem studied on 36 animals in predicting tenderness value at 192 hr post-mortem.

The step-wise regression analysis showed that when the steaks were cooked by broiling, the 48-hr panel tenderness score accounted for 40.96 per cent of the variability in panel tenderness score at 192 hr post-mortem. If the predicted value of panel tenderness at 192 hr post-mortem was Y than the predictive equation for Y, from the knowledge of panel tenderness at 48 hr (BPT48),

Table 26. Coefficients in predicting tenderness value at 192 hr post-mortem from tenderness values at 48, 24 and 1 hr.

Cooking method	Tenderness evaluation	Independent variable: Time post-mortem, hr	r_{XY}	R	Constant	Partial regression coefficient: b_1	b_2	b_3
Broiling	Panel	48	.64**[a]	.64**[b]	4.33747	.50133		
Broiling	Shear	48	.63**[a]	.63**[b]	.03935	.65566		
Broiling	Shear	1	-.33*[a]	.65**[b]	1.67403	.60657		-.22103
Deep fat	Panel	48	.61**[a]	.61**[b]	4.24074	.51776		
Deep fat	Panel	24	.20	.65**[b]	4.37440	.67353	-.24028	
Deep fat	Shear	48	.66**[a]	.66**[b]	-1.72822	.90731		

*[a] $P_{<}.05 = .33$
**[a] $P_{<}.01 = .42$
*[b] $P_{<}.05 = .40$
**[b] $P_{<}.01 = .48$

becomes Y = 4.33747 + .50133 (BPT 48). A one-unit increase in taste panel scores at 48 hr post-mortem would result in .50133 unit increase in taste panel scores at 192 hr post-mortem. The same relationship between tenderness at 192 hr and 48 hr was found when the shear method was used for evaluation. The 48-hr shear tenderness (BST 48) value accounted for 39.69 per cent of the variability in shear tenderness value at 192 hr post-mortem, and the predictive equation was: Y = .03935 +.65566 (BST 48). The second step in the regression analysis for the broiled steaks and shear tenderness included the 1-hr shear tenderness (ST 1) value, which had a simple correlation coefficient with the 192-hr value of -.33 and gave a multiple correlation coefficient of .65 when combined with the 48 hr shear tenderness value. Including the 1-hr shear tenderness value was found to account for only 2.56 per cent of the variability in shear tenderness value at 192 hr post-mortem, and the predictive equation was: Y = 1.67403 + .60657 (BST 48) - .22103 (BST 1).

The same analysis showed that the 48-hr panel tenderness score for the deep fat fried steaks (DPT 48) accounted for 37.21 per cent of the variability in panel tenderness score at 192 hr post-mortem, and the predictive equation was: Y = 4.24074 + .51776 (DPT 48). The second step in the regression analysis for the deep fat fried steaks and panel tenderness included the 24-hr panel tenderness score (DPT 24) which increased the multiple correlation coefficient from .61 to .65. Hence, including the 24 hr panel tenderness score was found to account for only 5.04 of the variability in panel tenderness score at 192 hr post-mortem and gave the predictive equation: Y = 4.37440 + .67353 (DPT 48) - .24028 (DPT 24). The 48-hr shear tenderness value (DST 48) accounted for the

highest per cent, 43.56, of the variability in shear tenderness value at 192 hr post-mortem and gave the predictive equation: $Y = -1.72822 + .90731$ (DST 48).

The relationship between nitrogen concentration in water soluble proteins and ultraviolet absorbance

Simple correlation coefficients between all variables are found in Table 27. For the four post-mortem intervals studied and for all samples when combined and analyzed as a total, highly significant ($P_{<}.01$) correlations were found between ultraviolet (UV) absorbance at 260 and 280 m_{μ}. Low, insignificant correlations were found between Nitrogen (N) concentration as measured by the Kjeldahl method and UV absorbance at 260 and 280 m_{μ} at 1 hr post-mortem. However, highly significant ($P_{<}.01$) correlations were found between N concentration and UV absorbance at 24 hr post-mortem. At 48 hr post-mortem, a significant ($P_{<}.05$) correlation was found between N concentration and UV absorbance at 260 m_{μ} while a low, insignificant correlation was found between N concentration and UV absorbance at 280 m_{μ}. At 192 hr post-mortem, the correlation coefficients between N concentration and UV absorbance at 260 and 280 m_{μ}, respectively, were highly significant ($P_{<}.01$) and significant ($P_{<}.05$). The eighty samples tested and represented by the total showed significant ($P_{<}.01$) correlations between N concentration and UV absorbance at both 260 m_{μ} and 280 m_{μ}. Higher correlation coefficients were found between N concentration and UV absorbance at 260 m_{μ} than at 280 m_{μ}. This was true for all periods and for the total. Since UV absorbance at 260 and 280 m_{μ} was due to the aromatic residues of tryptophan, tyrosin and phenylalanine (Haurowitz, 1963), these results would suggest some structural changes in the nature of the protein extracts.

Table 27. Simple correlation coefficients between nitrogen concentration in water soluble proteins and ultraviolet absorbance at 260 and 280 m_{μ}.

Time post-mortem, hr	1		24		48		192		Total	
UV absorbance, m_{μ}	260	280	260	280	260	280	260	280	260	280
UV absorbance at m_{μ}	.91**[a]	---	.87**[a]	---	.96**[a]	---	.90**[a]	---	.91**[b]	---
N concentration mg N/ml	.25	.19	.73**[a]	.68**[a]	.44*[a]	.35	.70**[a]	.51*[a]	.49**[b]	.37**[b]

*[a] $P_{<}.05 = .44$ *[b] $P_{<}.05 = .22$

**[a] $P_{<}.01 = .56$ **[b] $P_{<}.01 = .29$

Table 28 presents the simple, partial and multiple correlation coefficients for the most important variables in predicting N concentration at the four post-mortem intervals and for the total number of samples tested.

The multiple correlation coefficient between N concentration at 1 hr and UV absorbance at 260 m_{μ} was low, .25, and accounted for only 6.25 per cent of the variability in predicting N concentration.

At the 24 hr post-mortem period, the multiple correlation coefficient between N concentration and UV absorbance at 260 (A 260) was high and significant ($P_{<}.01$). Absorbance at 260 m_{μ} accounted for 53.29 per cent of the variability in predicting N concentration, and the predictive equation at this post-mortem time was: Y = .13151 + .51508 (A 260).

At the 48 hr post-mortem interval, the multiple correlation coefficient between N concentration and UV absorbance at 260 m_{μ} was insignificant, and only 19.36 per cent of the variability in predicting N concentration was due to 260 m_{μ} absorbance. The next variable entered at 48 hr was UV absorbance at 280, and this accounted for 6.65 per cent additional variability in predicting N concentration.

At the 192 hr post-mortem interval, a significant, ($P_{<}.01$) multiple correlation between 260 absorbance and N concentration was found. This variable accounted for 49.00 per cent of the variability in predicting N concentration, and the predictive equation was: Y = .13262 + .53939 (A 260). The next variable entered was 280 absorbance and this accounted for 8.75 per cent additional variability in predicting N concentration, and the predictive equation was: Y = .12586 + 1.00375 (A 260) - .67240 (A 280).

Table 28. Coefficients in predicting nitrogen concentration in water soluble proteins and ultraviolet absorbance at 260 and 280 m_{μ}.

Independent variable		r_{XY}	R	Constant	Partial regression coefficients	
					b_1	b_2
m_{μ}	Time post-mortem, hr					
260	1	.25	.25	.20662	.09866	
260	24	.73**[a]	.73**[c]	.13151	.51508	
260	48	.44*[a]	.44	.16023	.31096	
280	48	.35	.51	.15037	.87673	-.75099
260	192	.70**[a]	.70**[c]	.13262	.53939	
280	192	.51*[a]	.76**[c]	.12586	1.00375	-.67240
260	Total	.49**[b]	.49**[d]	.17123	.28595	
280	Total	.37**[b]	.52**[d]	.16604	.51430	-.30081

*[a] $P_{<}.05 = .44$ *[a] $P_{<}.05 = .22$ *[c] $P_{<}.05 = .53$ *[d] $P_{<}.05 = .27$
**[a] $P_{<}.01 = .56$ **[b] $P_{<}.01 = .29$ **[c] $P_{<}.01 = .63$ **[d] $P_{<}.01 = .33$

When all the 80 samples were analyzed statistically as one group regardless of time, a significant ($P_{<}.01$) correlation coefficient between N concentration and 260 m_{μ} absorbance was found. However, this variable accounted for only 24.01 per cent of the variability in predicting N concentration, which is low. The predictive equation for the estimation of N concentration from this variable was: $Y = .17123 + .28595$ (A 260). The next variable entered was 280 m_{μ} absorbance, and this accounted for only 3.03 per cent additional variability in predicting N concentration, even though the multiple correlation was significant ($P_{<}.01$). The predictive equation was: $Y = .16604 + .51430$ (A 260) - .30081 (A 280).

The step-wise regression analysis showed that UV absorbance at 280 m_{μ} added little in predicting N concentration from 260 absorbance. This was due to the very highly significant ($P_{<}.01$) correlations between 260 m_{μ} and 280 m_{μ} absorbance.

The relationship between nitrogen concentration in buffer soluble proteins and ultraviolet absorbance

Simple correlation coefficients between all variables are found in Table 29. For the four post-mortem intervals studied and for all samples, when the data were combined and analyzed as a total, highly significant ($P_{<}.01$) correlations were found between UV absorbance at 260 and 280 m_{μ}. Very low correlations, approaching zero, were found between N concentration as measured by the Kjeldahl method and UV absorbance at both 260 and 280 m_{μ} at the four post-mortem intervals and for the total.

Table 29. Simple correlation coefficients between nitrogen concentration in buffer soluble proteins and ultraviolet absorbance at 260 and 280 m_{μ}.

Time post-mortem, hr	1		24		48		192		Total	
UV absorbance, m_{μ}	260	280	260	280	260	280	260	280	260	280
UV absorbance at m_{μ}	.78**[a]	---	.85**[a]	---	.95**[a]	---	.91**[a]	---	.82**[b]	---
N concentration mg N/ml	.04	.01	.13	.04	.08	.04	-.05	.03	.09	.10

**[a] $P_{<}.01 = .56$

*[b] $P_{<}.05 = .22$
**[b] $P_{<}.01 = .29$

Post-mortem changes in solubility of the water and buffer soluble and buffer insoluble proteins

Mean values of nitrogen distribution between the various protein fractions for the 20 L. dorsi steaks used at each post-mortem time are shown in Table 30. The data obtained were analyzed for variance; levels of significance are shown in the above table.

No significant difference in amount of total nitrogen (expressed as mg N/g tissue) among the four post-mortem intervals was found. However, carcass differences in total nitrogen content of the L. dorsi were highly significant ($P < .005$). This was as anticipated since carcasses varied considerably in their marbling score (from average traces to average slightly abundant) as shown in Appendix Table 47.

Since the steaks used in this determination at the four post-mortem intervals were located at different positions along the length of the L. dorsi muscle, the above result that non-significant variations were found between the four intervals or within the length of the L. dorsi studied is quite important. This would emphasize the validity of using this muscle in meat research especially when homogeneity of raw materials within one carcass is required.

Differences between the four post-mortem intervals in amount of water soluble protein (WSP) (expressed as per cent of total N) were insignificant. The 20 animals used, however, showed significant variations in this respect. These data were in disagreement with data reported by Kronman and Winterbottom (1960) who found that aging and freezing of beef muscle for 7 days and 35 days, respectively, rendered the solubility of the water soluble proteins comparable to that of the 3-hr sample, and this was explained as being due to protein denaturation.

Table 30. Mean values of protein distribution of the L. dorsi of 20 animals.

Time, post mortem hr	1	24	48	192	Level of significance	
					Intervals	Animals
Total N mg N/g tissue	36.72	36.91	36.42	36.30	N.S.	.005
Std. deviation	1.47	1.23	1.31	1.21		
Std. error of mean	.33	.27	.29	.27		
WSP, % of total N	26.33	26.52	25.44	26.28	N.S.	.005
Std. deviation	3.05	3.37	3.00	3.58		
Std. error of mean	.68	.75	.67	.76		
BSP, % of total N	46.22	43.87	44.98	44.79	.005	.005
Std. deviation	2.39	2.39	2.17	1.97		
Std. error of mean	.53	.53	.49	.44		
BIP, % of total N	43.95	47.62	46.33	48.33	.005	.005
Std. deviation	3.91	3.41	2.90	4.46		
Std. error of mean	.88	.76	.65	1.00		
BIP/BSP	.95	1.09	1.03	1.08	.005	.005
Std. deviation	.10	.13	.08	.13		
Std. error of mean	.02	.03	.02	.03		

Also, these data do not support the report of Sayre and Briskey (1963) who found that the solubility of the sarcoplasmic protein extracted from the pigs' L. dorsi muscle decreased at 24 hr compared to that at 2 hr.

Post-mortem alterations in the solubility of the buffer soluble proteins (BSP)(expressed as per cent of total N) were highly significant ($P_{<}.005$). Solubility of the BSP at 1 hr post-mortem was higher than at any other period tested; sharp decline in protein solubility in buffer was observed during the first 24 hr during which the nitrogen content decreased from 46.22 per cent at 1 hr to 43.87 per cent at 24 hr post-mortem. Slight increases in protein concentration were observed at 48 and 192 hr; however, the average values at 48 and 192 hr were less than at 1 hr post-mortem. Animal variations in concentration of the BSP extracts were highly significant ($P_{<}.005$).

The amount of nitrogen in the buffer insoluble protein residue (BIP) (expressed as per cent of total N) were 43.95, 47.62, 46.33 and 48.33 per cent, respectively, at 1, 24, 48 and 192 hr post-mortem. Variations in nitrogen content of the residues between the four post-mortem times, as well as between animals, were highly ($P_{<}.005$) significant.

The ratio of nitrogen content, BIP/BSP, was significantly ($P_{<}.005$) different between the four post-mortem intervals. Animal variations in this ratio were also highly significant. While the minimum ratio of .95 was obtained at 1 hr, the maximum ratio of 1.09 was observed at 24 hr post-mortem. The ratios of 1.03 and 1.08 were found at 48 and 192 hr, respectively.

Even though the cause(s) of the solubility changes in the BSP extracts could not be explained thoroughly due to the fact that the protein components of

those extracts were not identified, the author believes that the sharp decline noticed in the solubility of proteins in the buffer solutions during the first 24 hr was due to the formation of cross links between the actin and myosin filaments of the myofibril. Therefore, the extraction of protein at 24 hr was probably not as easy as that at 1 hr post-mortem. This could also be the reason why proteins were less soluble in buffer at 48 and 192 hr post-mortem than at 1 hr.

The data obtained in this study indicate that autolysis was not the cause of the increased tenderness with aging for 8 days. If the breakdown of connective tissue was responsible for the increased tenderness observed after aging for 8 days, then, one should expect some increase in the BSP extracts and a corresponding decrease in BIP. The reversed situation was observed, however. The data of this study substantiate the work of Wierbicki et al. (1954) who found that increased tenderness with aging was not the result of changes in the nature of connective tissue.

The relationship between total tissue protein, water soluble, buffer soluble and buffer insoluble protein and tenderness

Simple correlation coefficients between tissue nitrogen, water soluble, buffer soluble and buffer insoluble nitrogen and tenderness are presented in Table 31. For the 20 animals used in the protein studies, panel tenderness scores were significantly ($P < .01$) correlated with shear tenderness values at the four post-mortem periods studied. Strikingly high correlation coefficients of -.92 and -.91 between panel tenderness and shear tenderness for steaks cooked by broiling and deep fat frying, respectively, were observed at the 192 hr post-mortem.

Table 31. Simple correlation coefficients between total, water soluble, buffer soluble and buffer insoluble protein and tenderness.

Time post-mortem, hr	1				24			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Tenderness as measured by panel	-.80	-.81			-.76	-.83		
Deep fat as measured by shear	.81				.91			
Deep fat as measured by panel			.86				.92	
Total N mg N/g tissue	-.01	.28	-.30	-.27	.11	.17	-.25	-.34
WSP, % of total N	-.18	-.00	-.05	.01	.07	-.03	.01	.16
BSP, % of total N	.35	.11	-.11	-.14	-.58**	-.49*	.51*	.51*
BIN, % of total N	-.24	-.21	-.02	-.10	.48*	.41	-.43	-.41
WSP/BSP	-.30	-.03	-.00	.06	.28	.18	-.19	-.07
BIP/BSP	-.38	-.23	.04	-.01	.58**	.50*	-.51*	-.50*

*$P_{<}.05 = .44$
**$P_{<}.01 = .56$

Table 31. (Cont.)

Time post-mortem, hr	48				192			
Tenderness measurement	Shear		Panel		Shear		Panel	
Cooking method	Br	DF	Br	DF	Br	DF	Br	DF
Tenderness as measured by panel	-.80	-.89			-.92	-.91		
Deep fat as measured by shear	.81				.91			
Deep fat as measured by panel			.88				.89	
Total N mg N/g tissue	.35	.14	-.40	-.33	.52*	.53*	-.54*	-.49*
WSP, % of total N	.11	.17	.14	-.04	.23	.19	-.23	-.24
BSP, % of total N	-.27	-.15	.31	.38	-.60**	-.56**	.48*	.55*
BIN, % of total N	.34	.37	-.40	-.29	.61**	.60**	-.49*	-.64**
WSP/BSP	.23	.25	-.00	-.21	.40	.36	-.36	-.40
BIP/BSP	.47*	.41	-.55*	-.49*	.70**	.68**	-.56**	-.70**

*$P_{<}.05 = .44$
**$P_{<}.01 = .56$

The two methods used in cooking, broiling and deep fat frying, as measured by the shear and panel tenderness values, were significantly ($P_{<}.01$) correlated with each other.

Total nitrogen content (expressed as mg N/g tissue) was significantly ($P_{<}.05$) correlated with the 192-hr tenderness value; steaks with higher nitrogen content were less tender. The correlation between this variable and tenderness values at the other post-mortem times studied, however, were low, insignificant, irregular and approached zero in one instance. While the significant correlation obtained in this study between total nitrogen content and tenderness at 192 hr post-mortem is in contrast to the report of Husaini et al. (1950a), the lack of agreement might be attributed to the difference in aging post-mortem. Other results of this study, at 1, 24 and 48 hr post-mortem, are in agreement with the same authors' report which showed no correlation between total nitrogen and tenderness at 14 days' post-mortem.

The correlation coefficients between the WSP (expressed as per cent of total tissue N) and tenderness values at the 192 hr post-mortem were low and insignificant. The correlations were irregular and approached zero at the other post-mortem periods.

While the correlations between the BSN (expressed as per cent of total tissue N) and tenderness were low at the 1-hr period, these two variables were significantly ($P_{<}.01$ for broiling and shear and $P_{<}.05$ for others) correlated at 24 hr. Again, low correlation coefficients between these two variables were found at 48 hr post-mortem. Protein solubility in buffer at the 192-hr post-mortem time, however, was significantly correlated ($P_{<}.01$ and $P_{<}.05$) with

shear and panel tenderness, respectively. These data appear to substantiate the report of Wierbicki et al. (1954) who found a highly significant correlation of .51 between panel tenderness and per cent of total nitrogen extracted by the buffer used in the author's study.

The correlation coefficients between the BIN (expressed as per cent of total tissue N) and 1 hr post-mortem tenderness were low for shear tenderness and approached zero for panel tenderness. At the 24-hr post-mortem period, the correlation coefficients between these variables were either significant ($P_{<}.05$ for broiled and shear) or approaching that level of significance. The correlation coefficients between these two variables at the 48-hr post-mortem period were insignificant and lower than that at the 24-hr period. The highest and most significant correlations between tenderness and the BIP were found at the 192-hr post-mortem period. All correlations were significant ($P_{<}.01$) at this period.

The correlation coefficients between the ratio WSP/BSP approached significance (at $P_{<}.05$) at the 192-hr post-mortem period. However, the correlations between this ratio and tenderness were low for all other post-mortem periods studied.

The ratio of the BIP/BSP was significantly ($P_{<}.01$) correlated with the 192-hr tenderness values. This ratio was significantly ($P_{<}.05$) correlated with the 48-hr tenderness values except for the shear tenderness of deep fat fried steaks where the correlation was approaching the same level of significance. Again, at the 24-hr period the two variables were significantly related ($P_{<}.05$). At 1 hr post-mortem, panel tenderness values and this ratio were not correlated. Even though the correlations between BIP/BSP and shear tenderness at

1 hr post-mortem were low, the correlations were negative; whereas at the three other periods studied the relationship was positive. The negative correlation between shear tenderness and the BIP/BSP ratio observed only at 1 hr post-mortem. The results agree essentially with work performed by Hegarty et al. (1963) but are contrary to some of the results obtained by Goll et al. (1964). Also, these data agree essentially with work performed by Hill (1962) who found that the characteristically tough muscle (Semitendinosus) was higher in stroma nitrogen content than the characteristically tender (L. dorsi) muscle of beef.

Post-mortem changes in viscosity of water and buffer soluble protein extracts

Table 32 gives the mean viscosity values of water and buffer soluble protein extracts.

The analysis of variance revealed that the slight differences in viscosity of the water soluble and buffer soluble protein extracts between either the four post-mortem intervals or between the 20 animals were not significant.

These data would indicate that post-mortem changes in the structure or shape of the proteins extracted with the water or buffer were either too small to affect viscosity or that the respective protein components of the two extracts were similar at the four post-mortem times.

The relationship between the viscosity of water and buffer soluble proteins and tenderness

Simple correlation coefficients between tenderness and the viscosity of water and buffer soluble proteins are presented in Table 33.

Table 32. Mean values of viscosity of water and buffer soluble protein extracts at four post-mortem intervals (20 carcasses).

Time post-mortem, hr	1	24	48	192	Level of Significance	
					Intervals	Animals
Viscosity of WSP, CPS	1.1473	1.1677	1.1403	1.1568	N.S.	N.S.
Std. dev.	.05	.05	.06	.05		
Std. error of mean	.01	.01	.01	.01		
Viscosity of BSP, CPS	1.3379	1.3108	1.3139	1.3002	N.S.	N.S.
Std. dev.	.07	.07	.07	.09		
Std. error of mean	.01	.01	.01	.02		

Table 33. Simple correlation coefficients between the viscosity of water and buffer soluble proteins and tenderness.

Time post-mortem, hr	Tenderness evaluation	Cooking method	Viscosity WSP	Viscosity BSP
	Shear	Br	.11	.06
		DF	.28	-.06
1				
	Panel	Br	.02	-.12
		DF	-.11	-.08
	Shear	Br	.01	-.13
		DF	-.05	-.07
24				
	Panel	Br	.17	.05
		DF	.30	.03
	Shear	Br	.24	.14
		DF	.33	.17
48				
	Panel	Br	-.44*	-.27
		DF	-.27	-.30
	Shear	Br	.23	-.15
		DF	.41	.04
192				
	Panel	Br	-.33	-.03
		DF	-.43	.03

*$P_{<}.05 = {<}.44$

**$P_{<}.01 = {<}.56$

For almost all variables analyzed, the viscosity of the WSP was either not correlated with tenderness, or the correlations were very low. In one case, however, a negative significant ($P_{<}.05$) correlation of -.44 between viscosity of the WSP and panel tenderness of the broiled steaks was found at 48 hr post-mortem. Correlation coefficients of .41 and -.43 (approaching the five per cent level of significance) between the viscosity of the WSP shear and panel tenderness of deep fat fried steaks, respectively, were found at 192 hr post-mortem. These correlations indicated that the viscosity of the WSP extracts was inversely related to the 192-hr tenderness values.

Table 33 shows no significant relationship between tenderness and the viscosity of the BSP at 1 and 24 hr post-mortem. The correlations between these variables were low at 48 hr post-mortem, as well as at 192 hr post-mortem. These data agree with data reported by Wierbicki et al. (1954) who found a low, insignificant correlation between tenderness and viscosity of the buffer soluble extract at 15 days post-mortem.

The electrophoretic separation of buffer and water soluble proteins

Characteristic patterns obtained from the buffer and water soluble proteins are represented in Figs. 20 and 21, respectively. In each figure, the lower part shows the electrophoretic pattern obtained on the gel strip from a sample separation. The upper part represents the diagrammatic sketch used for evaluation. For simplicity, and to enable the analysis of this determination statistically, the bands were numbered and grouped in zones. Zone A represented those proteins which migrated toward the anode; this is referred to as the anionic zone. Zone B represented those proteins which migrated toward the

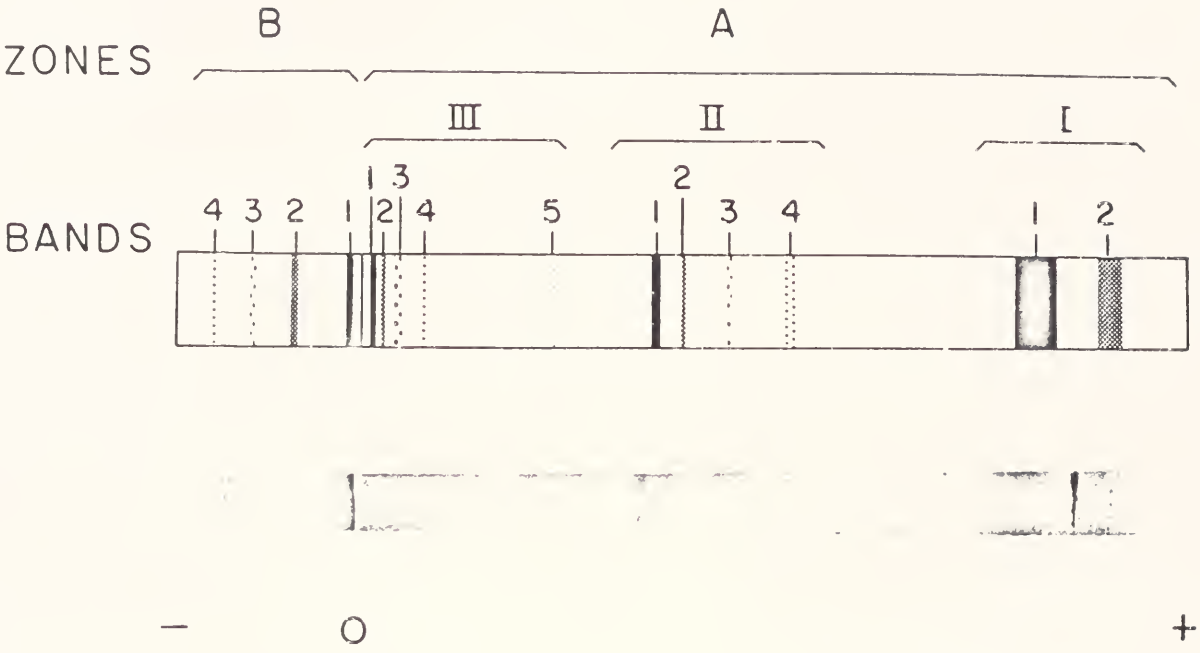

Fig. 20. Starch-gel Electrophoretic patterns of buffer soluble proteins.

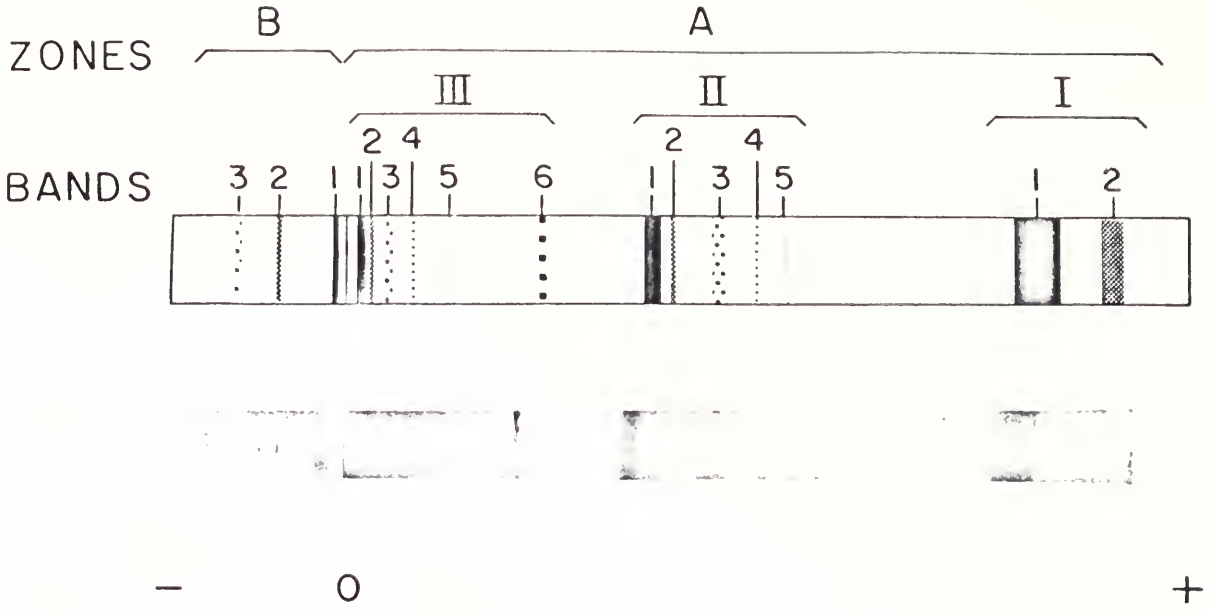

Fig. 21. Starch-gel electrophoretic patterns of water soluble proteins.

cathode; this is referred to as the cationic zone. Zone A was also divided into three sub-zones, numbered I, II and III in order of decreasing anionic mobility. In Figs. 20 and 21 the total number of bands appearing in the diagrammatic sketches do not represent any particular separation. The diagram represents the general picture or all possible combinations of bands that were obtained from the 20 carcasses and at the four post-mortem times. The number of bands obtained from the buffer and water soluble proteins are presented in Appendix Table 62 for each carcass at the four post-mortem intervals.

Post-mortem changes in electrophoretic components of the water and buffer soluble protein extracts

The average number of electrophoretic bands which appeared on the gel strips are shown in Table 34.

Non-significant differences in average number of bands in sub-zone I A, sub-zone II A, zone B and zone A & B between the water and buffer soluble protein extracts were found. However, these two extracts were significantly different in average number of bands in sub-zone III A and zone A.

Differences between the four post-mortem intervals were significant only for sub-zone II A, sub-zone III A and zone A. Time post-mortem had no significant effect on the number of bands in other zones observed.

Marked variations in the number of bands between animals were noted. Except for the number of bands in sub-zone I A, variations among animals in all other zones were highly ($P_{<}.005$) significant.

While the identification of the different electrophoretic components of the water and buffer soluble protein extracts was not the object of this study, the

Table 34. Mean values of number of electrophoretic bands obtained from water and buffer soluble proteins after starch gel electrophoresis (four post-mortem intervals of 20 carcasses).

Time post-mortem, hr	1		24		48		192		Level of Significance		
Protein solubility	WS	BS	WS	BS	WS	BS	WS	BS	Extract	Intervals	Animals
No. of bands in sub-zone IA	2.00	2.00	2.00	2.00	1.95	2.00	1.95	2.00	N.S.	N.S.	N.S.
Std. dev.	.00	.00	.00	.00	.22	.00	.22	.00			
Std. error of mean	.00	.00	.00	.00	.05	.00	.05	.00			
No. of bands in sub-zone IIA	3.35	3.65	3.25	3.60	3.25	3.60	3.15	3.50	N.S.	.05	.005
Std. dev.	.67	.59	.55	.60	.55	.60	.67	.76			
Std. error of mean	.15	.13	.12	.13	.12	.13	.15	.17			
No. of bands in sub-zone IIIA	3.60	2.60	4.00	2.80	4.00	2.75	3.65	2.20	.005	.005	.005
Std. dev.	.75	1.05	1.03	1.15	1.03	1.16	.99	1.14			
Std. error of mean	.17	.23	.23	.26	.23	.26	.22	.25			

Table 34. (Cont.)

Time post-mortem, hr	1		24		48		192		Level of Significance		
Protein solubility	WS	BS	WS	BS	WS	BS	WS	BS	Extract	Intervals	Animals
No. of bands in zone A	8.95	8.25	9.25	8.30	9.20	8.35	8.75	10.95	.05	.025	.005
Std. dev.	.60	1.37	.91	1.46	.95	1.42	.91	1.46			
Std. error of mean	.14	.31	.20	.33	.21	.32	.20	.33			
No. of bands in zone B	2.20	2.65	2.15	2.55	2.20	2.45	2.20	2.00	N.S.	N.S.	.005
Std. dev.	.62	.75	.67	.83	.70	.89	.70	.76			
Std. error of mean	.14	.17	.15	.19	.16	.20	.16	.17			
No. of bands in zone A & B	11.15	10.90	11.40	10.85	11.40	10.80	10.95	10.70	N.S.	N.S.	.005
Std. dev.	.88	1.89	1.23	2.01	1.27	2.04	1.24	1.95			
Std. error of mean	.20	.42	.28	.45	.29	.46	.28	.44			

mobility, intensity, width and shape of bands appearing on the gel strips, as well as the results of the statistical analysis demonstrated some similarity between most of the components of the water and buffer soluble protein extracts. Further, the writer observed that the color of the buffer and water soluble protein extracts was similar and that sub-zone I A of both extracts appeared with a faint brown color on the gel strips prior to staining. The above observations and the similarity in mobility and appearance between the bands of sub-zone I A and those obtained by Quinn et al. (1964), who identified three components in beef myoglobin extracts, indicated that the bands of this zone were two of the myoglobin components. Identification of other electrophoretic bands from the literature was not possible, because different procedures for protein extraction and electrophoretic analysis had been used.

The relationship between electrophoretic components of the water and buffer soluble proteins and tenderness

To examine the relationship between the number of bands that appeared on the starch gel and tenderness, simple correlation coefficient analysis was made for all variables. Table 35 presents the most important simple correlation coefficients obtained.

Generally, the correlations presented in Table 35 were low. However, some correlations between tenderness and number of bands of both water soluble and buffer soluble proteins were either significant ($P_{<}.05$) or approached significance. The total number of electrophoretic bands of the WSP were significantly ($P_{<}.05$) correlated with shear tenderness value of the deep fat fried steaks at the 24-hr post-mortem period. Also, the total number of bands of

Table 35. Simple correlation coefficients between the number of some electrophoretic bands of water and buffer soluble proteins and tenderness.

Time post-mortem, hr		1				24			
Tenderness measurement		Shear		Panel		Shear		Panel	
Cooking method		Br	DF	Br	DF	Br	DF	Br	DF
Protein solubility	Location of electrophoretic bands								
WS	Total number in zone A	-.05	-.09	.20	.07	.25	.39	-.21	-.36
WS	Total number in zone B	.33	.09	-.16	-.00	.34	.38	.01	-.05
WS	Total number in zone A and B	.21	.00	.03	.05	.37	.50*	-.15	-.29
BS	Total number in sub-zone IIA	-.03	-.24	.21	.15	-.21	-.19	.15	.04
BS	Total number in sub-zone IIIA	-.34	-.22	.19	.20	-.06	.04	-.36	-.30
BS	Total number in zone A	-.27	-.27	.23	.22	-.10	.03	-.22	-.27
BS	Total number in zone A and B	-.26	-.28	.21	.18	.00	.08	-.24	-.29

*$P_{<}.05 = .44$
**$P_{<}.01 = .56$

Table 35. (Cont.)

Time post-mortem, hr		48				192			
Tenderness measurement		Shear		Panel		Shear		Panel	
Cooking method		Br	DF	Br	DF	Br	DF	Br	DF
Protein solubility	Location of electrophoretic bands								
WS	Total number in zone A	.07	-.06	-.15	-.09	-.03	-.04	.04	.21
WS	Total number in zone B	.23	.05	-.16	-.16	.11	.12	-.03	.03
WS	Total number in zone A and B	.18	-.02	-.20	-.16	.04	.03	.01	.17
BS	Total number in sub-zone IIA	-.08	-.34	.25	.22	-.50*	-.40	.35	.50*
BS	Total number in sub-zone IIIA	-.19	-.00	-.12	.05	-.21	-.06	.23	.12
BS	Total number in zone A	-.19	-.14	-.00	.14	-.42	-.26	.36	.36
BS	Total number in zone A and B	-.12	-.15	-.06	.07	-.32	-.20	.28	.36

*$P_{<}.05 = .44$
**$P_{<}.01 = .56$

the BSP which appeared in sub-zone A II were significantly ($P_{<}.05$) correlated with shear tenderness values for the broiled steaks and with panel tenderness of deep fat fried steaks at 192 hr post-mortem. The correlations between sub-zone A II, and shear tenderness values of the deep fat fried steaks and panel tenderness values for the broiled steaks approached significance ($P_{<}.05$). The direction of the signs of these correlations indicated that the greater the number of bands in sub-zone A II, the more tender was the meat at 192 hr post-mortem.

The relative significance of chemical and physical factors influencing and/or associated with beef tenderness

The final statistical analysis conducted was based on the results obtained from previous statistical analyses. Here, the most important factors influencing and/or associated with tenderness of the broiled and deep fat fried L. dorsi steaks of 36 animals at 1, 24, 48 and 192 hr were pooled and analyzed by the step-wise regression program. For the 20 animals used in the protein studies, however, the step-wise regression program included additional factors.

The relative significance of factors influencing and/or associated with tenderness at 1 hr post-mortem

a. Steaks cooked by broiling

Simple correlations, step number (the order in which independent variable or variables entered the regression program), multiple correlations and per cent variability accounted for by a factor or combination of factors (the square of multiple correlation) for broiled steaks are shown in Table 36.

For the 36 animals, temperature at 1 hr post-mortem showed the highest simple correlation of -.55 ($P_{<}.01$) with panel tenderness and was the only variable entered in the step-wise regression program. This variable accounted for 30.25 per cent of the variability in predicting panel tenderness at 1 hr post-mortem. The above relationship was also true when tenderness was evaluated by shear. Here, however, two more variables were entered in the step-wise regression program. Cooking loss was the second variable entered and accounted for 8.05 per cent additional variability in 1-hr shear tenderness. The third variable entered was pH at 1 hr. This variable increased the multiple correlation coefficient from .61 to .68 and accounted for an additional 9.03 per cent of the variability in shear tenderness.

Table 36 shows the results obtained when the ratio BIP/BSP was added in the step-wise regression program of the 20 animals. Here also the greatest percentage of variance of tenderness by panel accounted for was by temperature at 1 hr post-mortem.

No relationship was found between panel tenderness and BIP/BSP. However, this variable was the third to enter the step-wise regression program and accounted for an additional 22.27 per cent of the variability in shear tenderness when combined with 1-hr pH and temperature.

The relationship between marbling score and tenderness of the 36 broiled steaks was very low, .04 and -.10 for panel and shear, respectively.

b. Steaks cooked by deep fat frying

Table 37 gives the relationship between the deep fat fried steak tenderness and the same variables considered with the broiled steak tenderness.

Table 36. The relationship between tenderness of the broiled L. dorsi steak at 1 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 1 hr	.41*				-.50**	3	.68	46.24
36	Temperature at 1 hr	-.55**	1	.55	30.25	.54**	1	.54	29.16
36	Bound moisture, %	-.08				-.09			
36	Free moisture, %	.06				.08			
36	Cooking loss, %	-.29				.34*	2	.61	37.21
36	Marbling score	.04				-.10			
20	pH at 1 hr	.42	2	.60	36.00	-.45*	1	.45	20.25
20	Temperature at 1 hr	-.47*	1	.47	22.09	.40	2	.57	32.49
20	Bound moisture, %	.26				-.07			
20	Free moisture, %	-.25				-.11			
20	Cooking loss, %	-.35				.35			
20	Marbling score	-.01				.18			
20	BIP/BSP	.04				-.38	3	.74	54.76

*$P_{<}.05$
**$P_{<}.01$

Table 37. The relationship between tenderness of the deep fat fried L. dorsi steak at 1 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 1 hr	.30				-.65**	2	.74	54.76
36	Temperature at 1 hr	-.49**	1	.49	24.01	.65**	1	.65	42.24
36	Bound moisture, %	-.12				-.13			
36	Free moisture, %	.07				.15			
36	Cooking loss, %	-.37*	2	.56	31.36	.47**	3	.78	60.84
36	Marbling score	.19				-.14			
20	pH at 1 hr	.38				-.41			
20	Temperature at 1 hr	-.41	1	.41	16.81	.41	2	.63	39.69
20	Bound moisture, %	.25				-.04			
20	Free moisture, %	-.24				.02			
20	Cooking loss, %	-.38	2	.54	29.16	.51*	1	.51	26.01
20	Marbling score	.05				-.13			
20	BIP/BSP	-.01				-.23			

*$P_{<}.05$
**$P_{<}.01$

Generally, the same relationship was found here. However, cooking loss showed a greater relationship with panel and shear tenderness of the deep fat fried steaks than with the broiled steaks.

The relationship between shear tenderness of the deep fat fried steaks and the ratio BIP/BSP was lower than with the broiled steak shear tenderness. Also, this variable failed to enter in the step-wise regression program.

The relationships between marbling scores of the 36 animals and tenderness of the deep fat fried steaks were also low, .19 and -.14 for panel and shear values, respectively.

The results obtained with the broiled and deep fat fried steaks would indicate, therefore, that the 1-hr post-mortem temperature was the most important factor influenced and/or associated with the 1-hr tenderness. Since the 1-hr muscle temperature was indicative of muscular activity or muscular contraction preceding or during death (Bate-Smith and Bendall, 1949; Briskey, 1959; Forrest et al., 1965 and Beecher et al., 1965), then the results obtained in this study would suggest that initial tenderness was mainly dependent on the degree of muscular contraction at 1 hr post-mortem. Therefore, the "toughness" of the steaks from the animals with higher muscle temperature could be due to the higher amount of cross links between actin and myosin compared to the "tender" steaks. This suggestion is in line with the report of Wierbicki et al. (1956) whose results also indicated that the amount of actomyosin was related to tenderness. However, the relationship obtained between the ratio of BIP/BSP and tenderness failed to support the above suggestion at 1-hr post-mortem. This discrepancy could be explained by the fact that while tenderness evaluation was conducted immediately after removing the steaks from the L. dorsi muscle,

the steaks used for protein studies were stored frozen until used for protein extraction and fractionation. Furthermore, the extraction and fractionation procedures required several hours for completion. These conditions were, therefore, suitable for the breakdown of actomyosin to actin and myosin due to the presence of ATP in the steaks removed at 1 hr post-mortem.

The relative significance of factors influencing and/or associated with tenderness at 24 hr post-mortem

a. Steaks cooked by broiling

The relative significance of factors influencing and/or associated with tenderness is shown in Table 38.

The rate of pH change at 11 hr post-mortem was positively associated with 25.00% of the variability in panel tenderness and was the first variable entering the step-wise regression analysis of the 36 animals. When pH at 1 hr was combined with rate of pH change at 11 hr post-mortem, the multiple correlation coefficient was increased from .50 to .56. This accounted for an additional 6.36% of the variation in panel score.

Cooking loss % was positively associated with 22.09% of the variability in shear tenderness value and was the only variable entering the step-wise regression program.

A non-significant correlation of .30 was found between marbling score and taste panel score for tenderness. However, when tenderness was evaluated by W-B shear, no correlation between marbling and tenderness was found.

The ratio of BIP/BSP was the first variable entered in the step-wise regression analysis of the 20 animals. This variable accounted for 26.01% and 34.81% of the variability in panel and shear tenderness, respectively. While

Table 38. The relationship between tenderness of the broiled L. dorsi steak at 24 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 1 hr	-.43**	2	.56	31.36	.28			
36	Rate of pH change at 11 hr post-mortem	.50**	1	.50	25.00	-.38*			
36	Bound moisture, %	-.12				.05			
36	Free moisture, %	-.03				.02			
36	Cooking loss, %	-.39*				.47**	1	.47	22.09
36	Marbling score	.30				-.02			
20	pH at 1 hr	-.36				.29			
20	Rate of pH change at 11 hr post-mortem	.47*				-.57**	3	.76	57.76
20	Bound moisture, %	-.33				.32			
20	Free moisture, %	.11				-.18			
20	Cooking loss, %	-.14				.50*			
20	Marbling score	.10				.02			
20	No. of bands in zone A (WSP)	-.21				.25			
20	No. of bands in zone A & B (WSP)	-.15				.37	2	.70	49.00
20	BIP/BSP	-.51*	1	.51	26.01	.58**	1	.59	34.81

*$P_{<}.05$
**$P_{<}.01$

the ratio BIP/BSP was the only variable which entered the step-wise regression analysis of panel tenderness, the number of bands in Zone A + B (WSP) was the second variable entering the step-wise regression program of shear tenderness. This variable, when combined with the ratio BIP/BSP increased the multiple correlation coefficient from .59 to .70. This accounted for an additional 14.19% of the variation in shear value.

b. Steaks cooked by deep fat frying

The results obtained are shown in Table 39. Generally, the relationship between panel tenderness of the deep fat fried steaks and pH at 1 hr and rate of pH change at 11 hr post-mortem was similar to that for the broiled steaks. However, the order in which the two variables entered the step-wise regression analysis was opposite to that noticed with the broiled steaks, where pH at 1 hr was the first variable entered.

While per cent cooking loss was the only variable entered in the step-wise regression program of the shear value of the broiled steaks, with the deep fat fried steaks, however, three variables entered. The order in which the variables entered was: rate of pH change at 11 hr post-mortem, cooking loss and pH at 1 hr, respectively.

The ratio BIP/BSP was also the first variable entered in the step-wise regression program of panel tenderness of the 20 deep fat fried steaks. This variable accounted for 25.00% of the variability in panel tenderness which was close to that observed with the panel tenderness of the broiled steaks, which was 26.01%. Here, however, the number of bands in Zone A (WSP) was associated with panel tenderness to a greater degree than was observed with the

Table 39. The relationship between tenderness of the deep fat fried L. dorsi steak at 24 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 1 hr	-.49**	1	.49	24.01	.38*	3	.65	42.25
36	Rate of pH change at 11 hr post-mortem	.48**	2	.58	33.64	-.42**	1	.42	17.64
36	Bound moisture, %	-.05				.05			
36	Free moisture, %	-.06				-.01			
36	Cooking loss, %	-.14				.38*	2	.57	32.49
36	Marbling score	.27				-.13			
20	pH at 1 hr	-.34				.19			
20	Rate of pH change at 11 hr post-mortem	.37				-.47*			
20	Bound moisture, %	-.35				.28			
20	Free moisture, %	.11				-.11			
20	Cooking loss, %	-.13				.27			
20	Marbling score	.18				-.05			
20	No. of bands in zone A (WSP)	-.36	2	.63	39.69	.39			
20	No. of bands in zone A & B (WSP)	-.29				.50*	1	.50	25.00
20	BIP/BSP	-.50*	1	.50	25.00	.50*	2	.72	51.84

*$P_{<}.05$
**$P_{<}.01$

broiled steaks. This variable, when combined with the ratio BIP/BSP, increased the multiple correlation coefficient from .50 to .63 and accounted for an additional 14.69% of the variation of panel score.

The number of bands in Zone A + B (WSP) and the ratio BIP/BSP were also the only variables entered in the step-wise regression program of shear tenderness of the deep fat fried steaks of the 20 animals. Similarly to the result obtained with the shear tenderness of the broiled steaks, these two variables, when combined, accounted for 51.84% of the variability in shear tenderness of the deep fat fried steaks.

The results obtained from the 36 animals indicated that the 24 hr tenderness was highly dependent on the rate of rigor mortis development and on cooking loss % to a lesser extent. When some of the muscle protein characteristics were included in the step-wise regression analysis of the 20 animals, the relationship obtained was different. Here, the ratio BIP/BSP was the most important factor associated with tenderness. Also, the number of certain electrophoretic bands appeared to be influencing or associated with tenderness.

Since the rate of pH drop was reported (Bate-Smith, 1948; Wierbicki et al., 1954 and Bendall, 1964) to be indicative of the rate of ATP breakdown, onw would expect a smaller amount of actomyosin at 24 hr post-mortem in carcasses undergoing faster rate of rigor. The author believes that the 24 hr tenderness was also dependent upon the amount of actomyosin formed. This postulation is supported by the fact that the ratio BIP/BSP was positively associated with tenderness at 24 hr post-mortem.

The relative significance of factors influencing and/or associated with tenderness at 48 hr post-mortem

a. Steaks cooked by broiling

The relative significance of factors influencing and/or associated with tenderness of the broiled steaks at 48 hr post-mortem is shown in Table 40.

The pH of the L. dorsi at 48 hr post-mortem was the only variable entered in the step-wise regression analysis of the panel and shear tenderness of the 36 animals. This variable accounted for 16.00% and 9.00% of the variance of tenderness by panel and shear, respectively. For the 20 animals, however, cooking loss was the first variable entered in the step-wise regression analysis of panel tenderness and accounted for 46.24% of the variance. The next variable entered was the viscosity of WSP. This variable accounted for 13.05% additional variance of panel tenderness. For shear tenderness, cooking loss was also the first variable entered and accounted for 27.04% of shear variance. However, pH at 48 hr was the second variable entered. This variable when combined with cooking loss % increased the multiple correlation coefficient from .52 to .66.

It may be noted in Table 40 that the correlations between tenderness of the 36 broiled steaks and marbling score were low with correlation coefficients of .24 and -.11 for tenderness evaluation by panel and shear, respectively.

b. Steaks cooked by deep fat frying

Table 41 shows that pH at 48 hr post-mortem was also the most important factor accounting for tenderness variability of both the panel and shear values of the 36 deep fat fried steaks. This factor explained 30.25% and 14.44% of panel and shear tenderness variability, respectively. Again, this

Table 40. The relationship between tenderness of the broiled L. dorsi steak at 48 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 48 hr	-.40*	1	.40	16.00	.30	1	.30	9.00
36	Bound moisture, %	-.21				.09			
36	Free moisture, %	.17				-.08			
36	Cooking loss, %	-.28				.22			
36	Marbling score	.24				-.11			
20	pH at 48 hr	-.34				.46*	2	.66	43.56
20	Bound moisture, %	-.45*				.39			
20	Free moisture, %	.44*				-.40			
20	Cooking loss, %	-.68**	1	.68	46.24	.52*	1	.52	27.04
20	Marbling score	.07				-.03			
20	BIP/BSP	-.55*				.47*			
20	Total N (mgN/g tissue)	-.40				.35			
20	Viscosity of WSP	-.44*	2	.77	59.29	.24			

*$P_{<}.05$
**$P_{<}.01$

Table 41. The relationship between tenderness of the deep fat fried L. dorsi steak at 48 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 48 hr	-.55**	1	.55	30.25	.38*	1	.38	14.44
36	Bound moisture, %	-.21				.13			
36	Free moisture, %	.17				-.19			
36	Cooking loss, %	-.20				.12			
36	Marbling score	.24				-.11			
20	pH at 48 hr	-.57**	1	.57	32.49	.55*	1	.55	30.25
20	Bound moisture, %	-.33				.34			
20	Free moisture, %	.40				-.40			
20	Cooking loss, %	-.15				.20			
20	Marbling score	-.06				-.08			
20	BIP/BSP	-.49*	2	.73	53.29	.41	2	.66	43.56
20	Total N (mgN/g tissue)	-.33				.14			
20	Viscosity of WSP	-.27				.33			

*$P < .05$
**$P < .01$

variable was the first to enter the step-wise regression program of the 20 animals. However, the ratio BIP/BSP was also entered in the analysis of the 20 animals. This ratio accounted for 20.80% and 13.31% additional variance of tenderness by panel and shear, respectively.

The same correlation coefficients between marbling scores and the broiled steaks' tenderness as evaluated by the panel and shear were observed with the deep fat fried steaks.

The results obtained from this analysis indicated that the 48-hr pH value was the most important factor influencing or associated with the 48-hr tenderness of the 36 animals. In addition to pH, cooking loss, viscosity of WSP and the ratio BIP/BSP were also found to explain some of the variation in tenderness value of the 20 animals.

The direction of the signs of correlations between pH and tenderness indicated an inverse relationship, that is, the lower the pH value at 48 hr the more tender the meat. This relationship could be due to level of feeding (Bate-Smith, 1948; Bate-Smith and Bendall, 1949 and Briskey, 1959). Other factors that might be involved in determining the ultimate pH value of muscle and hence the relationship between tenderness and pH were the rate of inactivation of glycolytic enzyme, rate of lactic acid production and the buffering capacity of muscle (Kronman and Winterbottom, 1960).

The author believes that the increased tenderness observed at 48 hr compared to 24 hr was due to actomyosin dissociation. This postualtion is supported by the increased buffer solubility of the protein extracts compared to that at 24 hr post-mortem. The writer also believes that the amount of free myosin and actin

exerted an effect on ultimate pH. This suggestion is based on Bendall's (1964) report that myosin contained about 160 acidic and 150 basic groups and that actin contained 120 and 110 groups per 100,000 g, respectively. The relationship found between the ratio BIP/BSP and tenderness at 48 hr post-mortem supports the author's belief.

The relative significance of factors influencing and/or associated with tenderness at 192 hr post-mortem

a. Steaks cooked by broiling

Table 42 shows the relative significance of factors influencing or associated with the broiled steaks tenderness at 192 hr post-mortem. The greatest percentage of variance of tenderness by panel and shear for the 36 animals at 48 hr was accounted for by pH. This variable explained 30.25% and 29.16% of panel and shear variance, respectively. Bound moisture ranked second in importance for tenderness as measured by panel and shear. This variable accounted for 13.31% and 14.40% additional variance of tenderness by the panel and shear, respectively. The last variable entered into the analysis of the panel and shear tenderness was cooking loss which, when combined with the first two variables, raised the multiple correlation coefficients from .66 to .71 and .66 to .70 for the panel and shear tenderness, respectively.

The above three variables were again entered in the panel analysis of the 20 animals. However, the order in which the first two variables entered the program was different than with the 36 animals. Here, bound moisture was the first to enter the step-wise regression analysis and was followed by pH at 48 hr post-mortem. Cooking loss was the last variable entered in the program.

Table 42. The relationship between tenderness of the broiled L. dorsi steak at 192 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 48 hr	-.55**	1	.55	30.25	.54**	1	.54	29.16
36	Bound moisture, %	-.48**	2	.66	43.56	.48**	2	.66	43.56
36	Free moisture, %	.48**				-.49**			
36	Cooking loss, %	-.27	3	.71	50.41	.25	3	.70	49.00
36	Marbling score	.19				-.15			
20	pH at 48 hr	-.58**	2	.76	57.76	.58**	3	.85	72.25
20	Bound moisture, %	-.65**	1	.65	42.25	.69**			
20	Free moisture, %	.65**				-.72**	1	.72	51.84
20	Cooking loss, %	-.24	3	.82	67.24	.24			
20	Marbling score	.13				-.07			
20	BIP/BSP	-.56**				.70**	2	.80	64.00
20	WSP (% of total N)	-.23				.23			
20	Total N (mgN/g tissue)	-.54*				.52*			
20	No. of bands in sub-zone IIA (BSP)	.35				-.50*			
20	Viscosity of WSP	-.33				.23			

*$P < .05$

**$P < .01$

This variable when combined with bound moisture and pH at 48 hr raised the multiple correlation coefficient from .76 to .82.

Free moisture accounted for 51.84% of the variability in shear values of the 20 animals and was the greatest single factor influencing tenderness evaluation by the W-B shear technique. The ratio BIP/BSP ranked second in importance and accounted for 12.16% additional variance of shear tenderness. pH at 48 hr was the third variable entered in the program. This variable, when combined with free moisture and the ratio BIP/BSP increased the multiple correlation from .80 to .85.

It is interesting that marbling score was able to account for only 3.61% and 2.25% of the variability in panel and shear tenderness scores, respectively, for the 36 animals.

b. Steaks cooked by deep fat frying

Table 43 gives the results obtained from the step-wise regression analysis of the deep fat fried steaks at 192 hr post-mortem.

pH at 48 hr was the first variable entered in the analysis of panel tenderness of the 36 animals and accounted for 36.00% of the variability in tenderness. The second variable entered was free moisture. This variable accounted for 7.56% additional variability in panel tenderness. For shear tenderness, however, free moisture was the first variable entered in the step-wise regression program. This variable accounted for 22.09% of the variability in shear tenderness of the 36 steaks. When pH at 48 hr was combined with free moisture, the multiple correlation coefficient was increased from .47 to .59. This increase accounted for 12.72% additional variability in shear tenderness.

Table 43. The relationship between tenderness of the deep fat fried L. dorsi steak at 192 hr post-mortem and selected chemical and physical measurements as shown by simple correlations and step-wise regression.

No. of animals	Variables	Panel				Shear			
		r xy	Step no.	R	Variability accounted for (%)	r xy	Step no.	R	Variability accounted for (%)
36	pH at 48 hr	-.60**	1	.60	36.00	.46**	2	.59	34.81
36	Bound moisture, %	-.39*				.43**			
36	Free moisture, %	.43**	2	.66	43.56	-.47**	1	.47	22.09
36	Cooking loss, %	.20				-.13			
36	Marbling score	.07				-.05			
20	pH at 48 hr	-.65**	2	.84	70.56	.51*	4	.89	79.21
20	Bound moisture, %	-.64**				.62**			
20	Free moisture, %	.70**				-.67**			
20	Cooking loss, %	.19				-.16			
20	Marbling score	.05				-.02			
20	BIP/BSP	-.70**	1	.70	49.00	.68**	1	.68	46.24
20	WSP (% of total N)	-.24	5	.95	90.25	.19			
20	Total N (mgN/g tissue)	-.49*				.53*			
20	No. of bands in sub-zone IIA (BSP)	.50*	3	.90	81.00	-.40	3	.81	65.61
20	Viscosity of WSP	-.43	4	.93	86.49	.41	2	.76	57.76

*$P_{<}.05$
**$P_{<}.01$

Evidently pH and bound or free moisture were the most important factors which explained the variations of final tenderness of the 36 animals. Since pH was significantly correlated with bound and free moisture, the results obtained clearly demonstrate the high dependence of final tenderness on the degree of hydration of the meat proteins.

The results obtained from the 20 animals strongly supported the role of muscle proteins in tenderness. Muscle protein characteristics studied such as solubility, viscosity and electrophoretic properties were all found to be related to tenderness.

Since final tenderness at 192 hr was highly and significantly dependent on 48-hr tenderness, the author believes that the amount of actomyosin is very important in determining final tenderness. The relationship found between the ratio BIP/BSP and tenderness at 192 hr definitely substantiates this suggestion.

Apparently, the increase in tenderness with aging was not due to actomyosin dissociation after 48 hr post-mortem. If actomyosin dissociation was responsible for the increased tenderness after 48 hr, one would expect some increase in the amount of buffer soluble protein. However, this was not true in this study. This suggestion is in line with the findings of Wierbicki et al. (1956).

Even though the results obtained in this study indicated clearly the close relationship between protein hydration and tenderness, the appreciable increase in tenderness with 8 days (192 hr) of aging was combined with decrease in pH and protein hydration. These results are therefore in contrast with those observed by Wierbicki et al. (1956) and with the concept that increased tenderness

Interestingly the ratio BIP/BSP was the first factor entered in the step-wise regression analysis of panel and shear tenderness of the 20 animals. This variable explained 49.00% and 46.24% of the panel and shear variability, respectively. This variable was able to account for more variability in panel scores than pH at 48 hr, number of bands in sub-zone II A (BSP), viscosity of WSP and WSP (% of total tissue N) combined. Also, the ratio accounted for more variability in shear tenderness than viscosity of WSP, number of bands in sub-zone II A (BSP) and pH at 48 hr combined.

The most interesting observation noted in the step-wise regression analysis of panel and shear tenderness of the 20 animals was that very high multiple correlation coefficients were obtained when the above mentioned factors were combined. In this study, the combination of BIP/BSP, pH at 48 hr, number of bands in sub-zone II A (BSP), viscosity of WSP and WSP (% of total tissue N) explained 90.25% of the variability in panel tenderness at 192 hr post-mortem. Also, the combination of BIP/BSP, viscosity of WSP, number of bands in sub-zone II A (BSP) and pH at 48 hr explained 79.21% of the variability in shear tenderness value at 192 hr post-mortem.

Table 43 revealed that marbling score had no relationship with panel and shear tenderness of the deep fat fried steaks at 192 hr post-mortem.

The results obtained from the 192-hr analysis clearly showed the close agreement between the factors associated with tenderness regardless of the methods used in evaluating tenderness. This was due to the very high correlations found between panel and shear values at 192 hr, as previously discussed.

with aging is due to increased protein hydration.

The author believes that the increased tenderness observed with 8 days (192 hr) of aging was mainly due to some physical changes in the conformation or arrangement of the proteins myosin and actin within the actomyosin molecule rather than complete dissociation of the actomyosin with aging.

SUMMARY AND CONCLUSIONS

Post-mortem changes in temperature, pH, water-holding capacity, cooking characteristics, Warner-Bratzler shear and palatability characteristics of the L. dorsi muscle were studied, using 36 crossbred steers averaging 437 kg at approximately 34 months of age. The L. dorsi muscles of 20 carcasses randomly selected from the 36 steers were used for muscle protein studies. Solubility, electrophoretic properties and viscosity of the water soluble and buffer soluble protein extracts were determined at 1, 24, 48 and 192 hr post-mortem. Ultraviolet measurements were made on the buffer and water soluble protein extracts to establish a relationship between nitrogen concentration as measured by the Kjeldahl method and ultraviolet absorbance.

The relationship of tenderness and other meat qualities to various chemical and physical measurements were determined.

Findings of this investigation are as follows:

1. The pH of the L. dorsi decreased with time post-mortem, rapidly for the first 15 hr and slowly thereafter; minimum values were obtained at 192 hr post-mortem. A low, but insignificant correlation was found between initial and ultimate pH.

2. A significant ($P_{<}.01$) correlation was found between initial shear tenderness values and pH of L. dorsi at 1 hr; higher pH values were associated with more tender steaks by both panel and shear tests. Tenderness values at

192 hr post-mortem were significantly ($P_{<}.01$) correlated with the 48-hr and 24-hr pH values; higher pH values were associated with less tender steaks by both panel and shear tests.

3. The L. dorsi temperature and pH showed a highly ($P_{<}.01$) significant correlation of -.52 at 1 hr post-mortem; higher temperatures were associated with lower pH values. However, pH values at 24, 48 and 192 hr post-mortem were not related to the 1-hr temperature values. Rate of pH change from 1 to 7, 9 and 11 hr post-mortem, and rate of temperature change from 1 to 3, 5, 7, 9 and 11 hr post-mortem, were significantly ($P_{<}.01$) correlated.

4. Tenderness values at 1 hr post-mortem were significantly ($P_{<}.01$) correlated with the 1 hr temperature values; higher temperature values were associated with less tender steaks by both panel and shear tests.

5. In general, water-holding capacity decreased with time post-mortem; maximum protein hydration was found at 1 hr and minimum hydration was found at 192 hr post-mortem; a significant ($P_{<}.01$) correlation of .53 between free moisture and time post-mortem was obtained. pH, the most important factor influencing protein hydration, was significantly ($P_{<}.01$) correlated ($r = -.73$) with free moisture.

6. Cooking loss increased significantly ($P_{<}.01$) with time post-mortem. pH, initial internal steak temperature, free moisture and cooking time were found to significantly ($P_{<}.01$) influence cooking loss.

7. The experienced panel judged the broiled steaks to be significantly ($P_{<}.01$) more juicy than the deep fat fried steaks. Juiciness scores showed low,

negative but significant ($P_{<}.01$) correlations to bound moisture and to cooking loss.

8. The broiled steaks were more flavorful than the deep fat fried ($P_{<}.005$). Aging the carcasses for 8 days was found to significantly ($P_{<}.01$) enhance the flavor of the steaks.

9. A negative, highly significant ($P_{<}.01$) correlation between Warner-Bratzler shear tenderness and taste panel tenderness was found at the four post-mortem intervals.

10. The steaks were tender at 1 hr, least tender at 24 hr and became progressively more tender with increased time post-mortem; maximum tenderness was obtained at the final test made at 192 hr post-mortem.

11. The 192-hr post-mortem tenderness values of the broiled and deep fat fried steaks as measured by panel and shear were highly dependent ($P_{<}.01$) on the 48-hr tenderness values and to a lesser extent on the 24-hr tenderness values. Shear tenderness values at 192 hr were inversely related (significant, $P_{<}.05$ for the broiled) to initial shear tenderness values at 1 hr post-mortem.

12. The relationship between nitrogen content (as determined by the Kjeldahl method) of water soluble protein extracts and UV absorbance at 260 and 280 m_{μ} was low at 1 hr post-mortem. Moderate correlations between the nitrogen content and UV absorbance were found at 48 hr; high and significant ($P_{<}.01$) correlations were obtained at 24 hr post-mortem.

13. Time post-mortem did not affect the amount of protein extracted with water. However, the amount of protein extracted with buffer was significantly ($P_{<}.005$) related to time post-mortem; maximum and minimum amounts

of protein were found in the 1-hr and 24-hr extracts , respectively. The author believes that the sharp decline in protein solubility at 24 hr post-mortem was due to actomyosin formation.

14. The relationship between tenderness values and the amount of nitrogen in the water soluble protein extracts was low and insignificant at 192 hr post-mortem. The correlations obtained between the above two factors at the other post-mortem periods were irregular and approached zero.

The amount of protein extracted with KCl-phosphate buffer (μ = 1.02, pH 6.8) was significantly ($P_{<}.01$) and ($P_{<}.05$) correlated with shear and panel tenderness values, respectively, at 192 hr post-mortem. However, the relationship between the above two factors was either moderate or low at the other post-mortem intervals.

Highly significant ($P_{<}.01$) correlations of .70 and .68 between the ratio of buffer insoluble protein to buffer soluble protein and shear tenderness of the broiled and deep fat fried steaks, respectively, were found at 192 hr post-mortem. Similar correlations were found between the same ratio and panel tenderness values at that period.

15. Post-mortem changes in viscosity of the water soluble and buffer soluble protein extracts were slight and insignificant.

The relationship between tenderness and viscosity was greater for the water soluble than for the buffer soluble protein extracts. Yet the relationship between tenderness and viscosity of the water soluble extracts was moderate at 48 and 192 hr post-mortem and low at 1 and 24 hr post-mortem.

16. Starch gel electrophoresis revealed a similarity between the protein components of the buffer soluble and water soluble protein extracts. Analysis of variance revealed no significant difference between the total number of bands appearing on the gel. However, a significant ($P_{<}.005$) difference in number of bands in the slowest anionic sub-zone was found between the water soluble and buffer soluble protein extracts.

Post-mortem time was found to significantly ($P_{<}.025$) affect the number of bands of the anionic zone.

Difference between animals in number of electrophoretic bands was rather extreme ($P_{<}.005$); except for fastest anionic sub-zone, which was tentatively identified as myglobin components.

Generally, the correlations obtained between tenderness and the number of electrophoretic bands were either low or approached zero. However, a significant ($P_{<}.05$) relationship was found between the number of certain anionic bands and 192-hr tenderness values.

17. The most important factors found to be associated with or influencing the 1-hr tenderness values were the L. dorsi temperature and pH at that time. The relationship obtained suggested that the degree of muscular contraction or the amount of cross links between actin and myosin at 1 hr was the most important factor determining the 1-hr tenderness values.

18. The most important factors found to be associated with or influencing the 24-hr tenderness values were the rate of rigor mortis development, as estimated by pH decline, cooking loss and the ratio buffer insoluble protein/ buffer soluble protein. The author believes that 24-hr tenderness was mainly

dependent on the amount of actomyosin in the L. dorsi at that time.

19. Factors found to be associated with or influencing the 48 hr tenderness values were 48-hr pH value, cooking loss and the ratio buffer insoluble protein/buffer soluble protein. The results suggest that the small improvement in tenderness observed at 48 hr compared to 24 hr was due to partial actomyosin dissociation.

20. Factors found to be associated with or influencing the 192-hr (8-day) tenderness values were the 48-hr pH, bound or free moisture, the amount of protein extracted with the KCl-phosphate buffer and the ratio buffer insoluble protein/buffer soluble protein. The results indicated that the increased tenderness with aging to 8 days was not the result of complete actomyosin dissociation and that variation in tenderness between animals was due to the amount of actomyosin present in muscle at that time. Further, the results of this study are in contradiction to the concept that the increased tenderness with aging may be due to increased protein hydration.

The author believes that the increased tenderness with 8 days' aging was mainly due to certain physical changes in the conformation or arrangement of the proteins, myosin and actin, within the actomyosin molecule.

21. Marbling was found to account for less than 4 per cent of the variability in tenderness of the broiled, L. dorsi steaks 8 days aged. For the deep fat fried steaks, marbling accounted for less than 0.5 per cent of the variability in tenderness, however.

In conclusion, this study had demonstrated the existence of an important relationship between tenderness and certain chemical and physical properties of beef proteins. Final tenderness was dependent on the chemical and physical

changes that occurred in the muscle during the first 48 hr following slaughter.

Further studies are needed to fully understand the nature of meat tenderness as influenced by the many physical and chemical changes occurring post-mortem.

APPENDIX

Table 44 . Description of scales used in evaluating carcass characteristics.

Characteristics studied	Descriptive term	Numerical scale
Color of lean	Very dark red	1
	Dark red	2
	Moderately dark red	3
	Cherry red	4
	Light cherry red	5
	Very light cherry red	6
	Dark pink	7
Texture of lean	Extremely coarse	1
	Very coarse	2
	Coarse	3
	Slightly coarse	4
	Moderately fine	5
	Fine	6
	Very fine	7
Firmness of lean	Extremely soft	1
	Very soft	2
	Soft	3
	Slightly soft	4
	Moderately firm	5
	Firm	6
	Very firm	7
Color of fat	White	1
	Cream	2
	Slightly yellow	3
	Very yellow	4

Table 44 . (Cont.)

Characteristics studied	Descriptive term	Numerical scale		
		-		+
Marbling	Devoid		0	
	Practically devoid	1	2	3
	Traces	4	5	6
	Slight	7	8	9
	Small	10	11	12
	Modest	13	14	15
	Moderate	16	17	18
	Slightly abundant	19	20	21
	Moderately abundant	22	23	24
	Abundant	25	26	27
	Very abundant	28	29	30
	Extremely abundant	31	32	33
Carcass grade and confirmation	Canner	1	2	3
	Cutter	4	5	6
	Utility	7	8	9
	Standard	10	11	12
	Good	13	14	15
	Choice	16	17	18
	Prime	19	20	21
Overall carcass maturity	A	1	2	3
	B	4	5	6
	C	7	8	9

Table 45 . Description of scales used in evaluating palatability characteristics.

Characteristics studied	Descriptive term	Numerical scale
Tenderness	Too tough to be edible	1
	Extremely tough	2
	Very tough	3
	Below average	4
	Average tenderness	5
	Above average	6
	Very tender	7
	Extremely tender	8
Juiciness	Too dry	1
	Extremely dry	2
	Very dry	3
	Below average	4
	Average juiciness	5
	Above average	6
	Very juicy	7
	Extremely juicy	8
Flavor	Completely bland	1
	Extremely bland	2
	Bland flavor	3
	Below average	4
	Average flavor	5
	Above average	6
	Very flavorful	7
	Extremely flavorful	8

Table 46 . Individual feed lot performance, in-transit shrink and carcass characteristics.

Treat. No.	Animal No.	Init. wt., kg	Final wt., kg	Av. daily gain, kg	In-transit shrink, %	Hot carcass wt., kg	Dressing %	Liver %	Carcass shrink %
1	100	444.5	582.9	1.19	2.85	335.7	63.5	.90	1.22
1	99	378.8	464.9	.74	5.85	256.7	59.2	1.10	1.24
1	95	381.0	485.4	.90	4.66	274.4	60.2	1.03	2.29
1	63	328.9	426.4	.84	4.92	241.8	61.2	.93	1.89
1	61	367.4	442.3	.65	6.47	248.6	60.1	1.08	3.23
1	70	358.3	446.8	.76	6.20	246.8	59.1	.93	.74
1	78	351.5	440.0	.76	7.65	261.3	65.3	1.32	1.39
1	73	306.2	408.2	.88	6.04	231.3	59.7	1.21	.78
1	71	367.4	449.1	.70	5.10	256.7	60.2	.96	1.41
2	97	385.6	535.2	1.29	8.73	279.9	60.2	1.07	1.30
2	180	421.9	560.2	1.19	4.68	318.9	59.5	1.14	1.84
2	181	362.9	476.3	.98	3.94	261.3	59.7	1.07	1.04
2	59	337.9	489.9	1.31	6.32	269.4	59.8	1.31	1.34
2	60	360.6	471.7	.96	7.62	259.9	59.1	1.18	1.05
2	69	394.6	492.2	.84	9.30	261.7	60.4	1.04	1.04
2	82	369.7	487.6	1.02	7.65	279.0	61.4	1.14	1.30
2	79	342.5	433.2	.78	7.89	242.7	60.1	1.07	1.48
2	72	303.9	394.6	.78	9.66	205.9	58.6	1.08	1.75

Table 46 . (Cont.)

Treat. No.	Animal No.	Init. wt., kg	Final wt., kg	Av. daily gain, kg	In-transit shrink, %	Hot carcass wt., kg	Dressing %	Liver %	Carcass shrink %
3	98	376.5	530.7	1.33	6.08	285.8	59.3	1.16	1.89
3	96	403.7	537.5	1.15	4.60	306.6	62.6	1.10	1.48
3	159	369.7	496.7	1.09	6.04	265.8	57.5	.99	1.38
3	62	365.2	455.9	.78	6.43	254.5	59.4	1.12	1.06
3	65	378.8	464.9	.74	5.66	268.5	61.5	1.03	1.02
3	64	337.9	451.3	.98	6.63	231.8	57.6	1.07	1.19
3	81	319.8	415.0	.82	5.95	229.1	58.1	.94	.80
3	76	322.1	412.8	.78	8.95	233.6	59.2	1.22	1.56
3	74	378.8	440.0	.48	6.56	263.5	61.5	.98	1.38
4	93	406.0	517.1	.96	3.45	319.3	62.9	1.12	.85
4	92	374.2	503.5	1.11	6.25	287.6	60.4	1.09	1.26
4	91	399.2	535.2	1.17	8.17	311.2	62.3	1.26	1.16
4	66	358.3	455.9	.84	7.01	266.3	61.3	1.17	1.04
4	68	360.6	453.6	.80	7.59	254.5	60.0	1.16	.71
4	67	362.9	453.6	.78	6.87	266.7	66.1	1.02	1.08
4	80	358.3	453.6	.82	7.11	257.6	62.1	1.23	1.79
4	75	331.1	446.8	1.00	7.39	245.4	56.1	1.03	1.10
4	77	335.7	421.9	.74	6.95	230.9	58.8	.87	1.56

Table 47 . Individual carcass grade data.

Treat. No.	Animal No.	Marbling	Conformation	Overall carcass maturity	Color of lean	Texture of lean	Firmness of lean	Color of fat	Carcass grade	Rib eye area, sq cm	Adj. fat over eye, cm	Est. kidney fat, %	Est. yield, %	Yield grade
1	100	6	15	3	5	5	5	2	13	37.59	1.02	1.5	52.76	2.15
1	99	14	15	4	4	5	5	3	15	27.10	.76	2.0	51.61	2.65
1	95	12	14	4	5	5	5	4	14	25.22	.64	1.5	51.26	2.80
1	63	8	13	3	4	5	5	2	13	21.95	1.27	3.0	48.85	3.85
1	61	12	15	3	4	5	6	2	15	22.40	1.02	3.0	49.31	3.65
1	70	5	12	3	4	5	6	2	11	17.53	.76	2.5	48.73	3.90
1	78	5	15	4	5	4	4	2	12	36.37	1.27	2.5	52.76	2.15
1	73	11	15	3	5	5	3	3	15	29.06	.38	3.0	52.99	2.05
1	71	20	14	3	4	4	6	3	17	27.23	1.02	2.5	52.53	2.25
2	97	10	14	4	4	5	5	2	14	27.74	.51	2.0	51.84	2.55
2	180	5	14	4	4	5	4	3	12	30.63	.64	2.0	51.61	2.65
2	181	8	15	4	4	4	5	2	13	29.59	.76	2.5	51.95	2.50
2	59	9	14	4	4	5	5	2	13	27.43	.51	2.5	51.72	2.60
2	60	8	15	3	4	5	4	2	14	28.19	.76	3.0	51.15	2.85
2	69	8	13	5	2	4	4	2	12	29.26	1.14	2.0	51.26	2.80
2	82	13	15	3	4	5	5	2	15	25.91	1.40	3.0	48.96	3.80
2	79	14	15	4	4	5	5	3	15	28.98	.89	3.0	51.72	2.60
2	72	9	13	3	4	5	5	2	13	23.47	.38	2.0	52.18	2.40

Table 47. (Cont.)

Treat. No.	Animal No.	Marbling	Conformation	Overall carcass maturity	Color of lean	Texture of lean	Firmness of lean	Color of fat	Carcass grade	Rib eye area, sq cm	Adj. fat over eye, cm	Est. kidney fat, %	Est. yield, %	Yield grade
3	98	12	13	5	5	6	6	3	14	21.87	1.02	2.0	48.85	3.85
3	96	11	14	5	4	4	6	4	13	29.24	.64	2.0	51.49	2.70
3	159	8	13	4	5	5	6	2	12	21.74	.51	3.0	50.00	3.35
3	62	13	14	4	3	5	6	3	15	23.01	.76	2.5	50.11	3.30
3	65	7	14	4	3	4	5	2	13	25.70	.89	3.0	50.23	3.25
3	64	8	12	5	2	4	4	2	12	26.47	.64	2.0	52.18	2.40
3	81	12	13	4	5	5	5	3	14	26.11	.64	2.5	51.84	2.55
3	76	6	15	2	5	5	4	3	13	33.35	.51	2.5	54.02	1.60
3	74	13	12	4	4	5	5	3	14	27.74	.76	3.5	50.92	2.95
4	93	11	15	4	4	5	5	3	15	29.11	1.27	3.0	49.31	3.65
4	92	12	15	4	5	4	5	2	15	31.50	.76	3.0	51.72	2.60
4	91	7	15	5	3	3	3	3	12	32.92	.76	2.5	51.95	2.50
4	66	11	14	3	4	5	5	2	14	25.15	1.02	4.0	49.31	3.65
4	68	7	15	4	3	4	6	2	13	30.43	1.02	3.5	50.80	3.10
4	67	7	13	5	3	5	5	2	12	21.36	.76	2.0	49.65	3.50
4	80	13	15	3	4	4	5	3	15	27.00	.76	3.0	51.15	2.85
4	75	13	14	3	5	5	5	4	15	28.40	1.02	2.5	51.38	2.75
4	77	12	15	3	4	5	5	3	15	24.41	.76	2.5	51.03	2.90

Table 48 . Post-mortem changes in temperature of L. dorsi muscle of 36 animals.

Post-mortem time, hr		0	1	2	3	4	5	6	7	8	9	10
Treat. No.	Animal No.											
1	100	39.5	39.5	36.0	31.5	28.0	25.0	22.0	20.0	18.0	16.5	15.0
1	99	39.0	39.0	36.0	31.0	26.5	23.0	21.0	18.5	17.0	15.0	13.0
1	95	40.0	41.0	38.5	35.0	31.0	27.0	25.0	22.0	20.5	18.5	16.5
1	63	40.0	38.5	33.0	27.0	23.0	20.0	18.0	15.0	12.0	11.0	9.5
1	61	40.0	40.0	36.0	28.0	24.0	21.0	18.0	16.0	14.0	12.0	10.0
1	70	38.5	38.0	34.0	29.0	24.0	20.0	18.0	16.0	13.0	11.0	10.0
1	78	40.0	39.5	37.0	32.0	27.0	23.0	20.0	17.0	15.0	13.0	11.0
1	73	40.0	40.5	36.0	29.0	24.0	21.0	19.0	18.0	13.0	11.0	10.0
1	71	38.5	38.5	38.0	36.0	26.0	24.0	21.0	17.0	13.0	9.0	9.0
2	97	39.5	39.5	36.0	30.5	26.0	22.0	19.0	17.0	14.0	13.0	11.5
2	180	40.0	40.0	39.5	36.0	31.5	27.0	24.0	21.5	19.0	17.5	15.0
2	181	40.0	40.0	35.5	31.0	27.0	26.0	22.0	20.0	18.0	16.0	14.5
2	59	39.0	39.0	34.0	27.0	22.0	19.0	16.0	13.5	11.0	10.0	8.0
2	60	38.5	38.5	37.0	30.0	26.0	22.0	20.0	17.0	15.0	13.5	12.0
2	69	41.0	40.0	32.0	24.0	20.0	17.0	15.0	12.0	9.0	8.0	5.0
2	82	39.0	38.0	34.0	29.0	28.0	20.0	18.0	16.0	13.0	11.0	9.0
2	79	43.0	42.0	39.0	31.0	25.0	23.0	20.0	17.0	15.0	12.0	10.0
2	72	41.0	40.0	33.0	26.0	22.0	16.0	14.0	12.0	12.0	12.0	6.0

Table 48 . (Cont.)

Post-mortem time, hr		0	1	2	3	4	5	6	7	8	9	10
Treat. No.	Animal No.											
3	98	39.5	39.5	39.0	35.0	32.0	28.0	25.5	23.5	21.5	20.0	18.5
3	96	39.5	40.0	34.0	29.0	25.0	22.0	19.0	17.0	15.0	12.5	10.5
3	159	40.0	38.0	32.0	24.5	20.5	18.0	15.0	12.0	9.5	8.0	6.0
3	62	38.5	38.0	35.0	30.0	23.0	19.5	16.0	14.0	12.0	10.0	8.5
3	65	40.5	41.0	37.0	32.0	26.0	24.0	20.0	17.0	15.0	13.0	10.0
3	64	41.5	39.5	31.0	27.0	21.0	17.0	14.0	12.0	9.0	7.0	5.0
3	81	39.5	38.0	34.0	26.0	22.0	19.0	16.0	13.0	11.0	10.0	9.0
3	76	41.0	40.0	35.0	30.0	28.0	27.0	16.0	12.0	12.0	9.0	7.0
3	74	39.0	38.5	36.0	29.0	22.0	18.0	16.0	14.0	12.0	10.0	8.0
4	93	39.5	40.0	38.0	34.0	30.0	27.0	24.0	21.0	18.5	16.5	14.5
4	92	39.5	39.5	36.5	30.5	25.0	20.5	17.0	14.0	11.5	9.5	8.0
4	91	39.5	39.5	38.0	34.5	30.0	26.5	23.0	20.5	18.0	16.5	15.0
4	66	40.0	40.0	37.0	33.0	29.0	27.0	26.0	21.0	20.0	17.0	15.0
4	68	39.5	39.0	35.0	30.0	26.0	32.0	20.0	17.0	15.0	13.0	11.0
4	67	39.5	40.0	34.0	28.0	23.0	22.0	17.0	15.0	13.0	11.0	9.0
4	80	39.0	39.0	36.0	29.0	25.0	22.0	17.0	16.0	13.0	12.0	10.0
4	75	39.5	39.0	36.0	31.0	26.0	23.0	19.0	17.0	16.0	15.0	12.0
4	77	41.0	40.0	35.0	26.0	23.0	18.0	14.0	11.0	9.0	8.0	7.0
Mean		39.79	39.44	35.64	30.04	25.49	22.40	19.01	16.46	14.24	12.44	10.53
Std. deviation		.94	.94		5.32		3.73		3.25		3.27	
Std. error of mean		.16	.16		.89		.62		.54		.55	

Table 48 . (Cont.)

Post-mortem time, hr		11	12	13	14	15	16	17	18	19	20
Treat. No.	Animal No.										
1	100	13.5	12.0	11.5	10.0	9.0	8.0	7.0	6.5	5.5	5.0
1	99	12.0	10.0	9.0	7.0	6.0	5.0	4.0	3.5	3.0	2.5
1	95	14.0	12.0	10.5	9.0	7.5	6.5	5.5	5.0	4.0	3.5
1	63	8.0	7.0	6.0	5.0	4.0	3.0	3.0	2.5	1.5	1.5
1	61	8.0	7.0	6.5	6.0	5.0	4.0	3.0	3.0	2.5	2.0
1	70	9.0	7.0	6.0	5.0	4.0	3.5	2.5	2.0	1.5	1.0
1	78	9.0	7.0	5.5	5.0	4.5	4.0	3.0	2.0	2.0	1.5
1	73	9.0	8.0	7.0	5.0	4.0	3.0	2.0	1.0	1.0	1.0
1	71	8.0	8.0	8.0	8.0	6.5	6.0	5.0	4.0	3.5	2.5
2	97	9.5	8.0	7.0	6.0	5.0	4.5	3.5	2.5	2.5	2.0
2	180	13.0	12.0	10.0	9.0	8.0	7.0	6.0	5.0	4.0	4.0
2	181	13.0	11.5	10.0	9.0	8.0	7.0	6.0	5.0	4.5	4.0
2	59	7.5	6.0	5.0	4.0	3.0	3.0	2.0	1.5	1.5	1.0
2	60	10.0	9.0	8.0	6.0	5.0	5.0	4.0	3.5	2.5	2.0
2	69	4.0	3.5	3.0	2.0	2.0	2.0	1.5	1.0	0.5	0.0
2	82	8.0	6.0	5.0	4.5	4.0	3.5	3.0	2.0	2.0	2.0
2	79	8.0	6.0	5.5	5.0	4.0	3.0	3.0	2.0	1.0	0.5
2	72	5.0	4.0	3.5	3.5	3.0	3.0	2.5	2.0	1.0	1.0

Table 48 . (Cont.)

Post-mortem time, hr		11	12	13	14	15	16	17	18	19	20
Treat. No.	Animal No.										
3	98	17.0	15.0	14.0	11.0	10.0	9.0	8.5	7.5	7.0	5.5
3	96	8.5	7.0	6.0	5.0	4.5	4.0	3.0	2.5	2.0	2.0
3	159	4.5	4.0	3.0	2.5	2.0	2.0	2.0	1.5	1.5	1.0
3	62	7.0	6.0	5.0	5.0	4.0	4.0	3.0	2.0	2.0	1.5
3	65	9.0	7.5	6.5	6.0	5.0	4.0	3.5	3.0	3.0	2.0
3	64	4.0	3.0	2.5	2.0	1.5	1.0	1.0	1.0	1.0	1.0
3	81	7.0	6.0	5.0	3.0	2.0	2.0	1.0	1.0	1.0	1.0
3	76	5.0	4.0	3.0	2.0	1.5	1.0	1.0	1.0	0.5	0.5
3	74	8.0	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0	2.0
4	93	13.0	11.0	9.5	8.0	7.0	6.0	5.5	4.5	4.0	3.5
4	92	7.0	6.0	5.0	4.5	3.5	3.0	2.0	2.0	1.5	1.5
4	91	14.0	12.0	11.0	10.0	8.5	7.5	6.5	6.0	5.0	5.0
4	66	15.0	13.5	12.0	10.0	10.0	10.0	9.5	9.0	8.5	8.0
4	68	10.0	8.0	7.0	6.0	5.5	5.0	4.5	4.0	3.5	3.0
4	67	7.0	5.5	4.5	4.0	3.5	2.5	2.0	2.0	1.5	1.0
4	80	9.0	7.0	6.0	5.0	4.0	3.5	3.0	2.5	2.5	2.0
4	75	11.0	8.0	7.0	6.5	6.0	5.0	4.0	3.0	2.0	1.0
4	77	6.0	5.5	4.0	3.5	3.0	2.0	1.0	1.0	0.5	0.5
Mean		9.18	7.75	6.76	5.78	4.96	4.44	3.65	3.08	2.61	2.19
Std. deviation		3.24		2.82		2.31		2.07		1.81	
Std. error of mean		.54		.47		.39		.35		.30	

Table 48 . (Cont.)

Post-mortem time, hr		21	22	23	24	28	32	36	40	44	48
Treat. No.	Animal No.										
1	100	4.5	3.5	3.0	3.0	2.0	1.0	1.0	0.5	0.0	0.0
1	99	2.0	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.0	0.0
1	95	3.0	2.5	2.0	2.0	1.0	0.5	0.5	0.0	0.0	0.0
1	63	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
1	61	1.5	1.5	1.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0
1	70	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5
1	78	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.0	0.0	0.0
1	73	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	71	2.0	2.0	2.0	1.5	0.0	0.0	0.0	1.0	0.5	0.0
2	97	2.0	2.0	1.5	1.5	1.0	1.0	0.5	0.0	0.0	0.0
2	180	4.0	3.0	3.0	2.5	1.5	1.0	1.0	0.0	0.0	0.0
2	181	3.5	3.0	2.5	2.5	1.5	1.0	1.0	0.5	0.0	0.0
2	59	1.0	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
2	60	2.0	2.0	2.0	2.0	0.5	0.0	0.0	0.0	0.0	0.0
2	69	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	-0.5
2	82	1.0	1.0	1.0	0.5	0.5	0.5	0.0	0.0	0.0	0.0
2	79	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	72	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0

Table 48 . (Cont.)

Post-mortem time, hr		21	22	23	24	28	32	36	40	44	48
Treat. No.	Animal No.										
3	98	5.0	4.5	4.0	3.0	2.0	1.5	1.0	1.0	1.0	1.0
3	96	2.0	1.5	1.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0
3	159	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.0	0.0
3	62	1.5	1.0	1.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0
3	65	2.0	2.0	1.0	1.0	0.5	0.5	0.0	0.0	0.0	0.0
3	64	1.0	1.0	1.0	1.0	1.0	0.5	0.0	-0.5	-0.5	-0.5
3	81	1.0	0.5	0.5	0.5	0.5	0.5	0.0	0.0	0.0	0.0
3	76	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	74	1.5	1.5	1.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0
4	93	3.0	3.0	2.0	2.0	1.5	1.0	1.0	0.5	0.5	0.5
4	92	1.0	1.0	1.0	1.0	0.5	0.5	0.5	0.0	-0.5	0.0
4	91	4.5	4.0	3.5	3.0	2.0	1.5	1.0	0.5	0.5	0.0
4	66	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.5	0.0	0.0
4	68	2.0	2.0	1.5	1.0	1.0	0.5	0.0	0.0	0.0	0.0
4	67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.5	-0.5
4	80	2.0	1.5	1.0	1.0	0.5	0.5	0.5	0.5	0.0	0.0
4	75	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
4	77	0.5	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0
Mean		1.89	1.63	1.38	1.15	.68	.46	.36	.15	.03	- .06
Std. deviation		1.54			1.39			.42			.25
Std. error of mean		.26			.23			.07			.04

Table 49 . Post-mortem changes in pH of L. dorsi muscle of 36 animals.

Post-mortem time, hr		1	2	3	4	5	6	7	8	9	10
Treat. No.	Animal No.										
1	100	7.10	6.85	6.50	6.40	6.20	6.10	6.20	6.10	5.90	5.90
1	99	6.90	6.85	6.70	6.50	6.30	6.30	6.00	5.85	5.70	5.65
1	95	6.70	6.45	6.00	6.00	5.90	5.75	5.60	5.60	5.50	5.60
1	63	7.00	7.00	7.00	6.95	6.80	6.70	6.70	6.60	6.50	6.30
1	61	6.80	6.55	6.40	6.10	6.20	6.10	6.00	5.80	5.90	5.80
1	70	7.00	6.90	6.85	6.70	6.50	6.45	6.45	6.20	6.15	5.90
1	78	6.70	6.60	6.30	6.30	6.30	6.00	6.00	5.90	5.85	5.70
1	73	6.40	6.20	6.10	6.00	5.95	6.00	5.90	5.85	5.80	5.70
1	71	7.00	6.80	6.80	6.60	6.40	6.30	6.20	6.20	6.20	6.10
2	97	7.00	6.70	6.40	6.25	6.10	5.70	5.70	5.80	5.70	5.75
2	180	6.90	6.50	6.35	6.10	5.90	5.90	5.80	5.70	5.65	5.55
2	181	7.00	6.85	6.55	6.40	6.20	6.05	6.00	5.95	5.70	5.70
2	59	6.80	6.75	6.50	6.50	6.30	6.20	6.10	6.00	6.00	5.90
2	60	6.90	6.90	6.90	6.70	6.65	6.50	6.30	6.30	6.20	6.20
2	69	6.80	6.60	6.50	6.40	6.20	6.20	6.10	6.00	6.00	6.00
2	82	7.10	7.10	7.00	6.90	6.95	6.90	6.60	6.50	6.35	6.30
2	79	6.30	6.00	5.95	5.85	5.75	5.65	5.65	5.70	5.65	5.65
2	72	6.80	6.80	6.70	6.40	6.30	6.30	6.30	6.30	6.20	6.00

Table 49 . (Cont.)

Post-mortem time, hr		1	2	3	4	5	6	7	8	9	10
Treat. No.	Animal No.										
3	98	6.93	6.30	6.15	6.00	5.80	5.70	5.65	5.60	5.65	5.60
3	96	6.85	6.70	6.40	6.20	6.20	6.10	6.00	5.75	5.80	5.60
3	159	6.80	6.60	6.50	6.40	6.20	6.20	6.05	5.70	6.05	5.85
3	62	6.90	6.90	6.90	6.70	6.70	6.55	6.40	6.40	6.30	6.30
3	65	6.80	6.70	6.40	6.30	6.20	6.00	5.90	5.90	5.80	5.80
3	64	6.90	6.50	6.50	6.35	6.25	6.20	6.10	6.10	6.05	6.00
3	81	6.80	6.80	6.75	6.75	6.60	6.50	6.40	6.20	6.10	6.10
3	76	6.80	6.70	6.50	6.30	6.30	6.20	6.20	6.20	6.00	5.95
3	74	7.00	7.00	7.00	6.85	6.70	6.50	6.50	6.40	6.25	6.25
4	93	7.10	7.00	6.80	6.70	6.65	6.50	6.30	6.20	6.10	6.00
4	92	7.00	6.65	6.45	6.40	6.20	6.20	6.10	6.00	5.90	5.90
4	91	7.10	7.00	6.75	6.65	6.60	6.50	6.30	6.20	6.20	6.10
4	66	6.90	6.80	6.60	6.50	6.30	6.20	6.10	5.90	5.90	5.90
4	68	6.85	6.50	6.40	6.20	6.20	6.10	6.10	6.10	5.90	5.90
4	67	6.70	6.60	6.30	6.00	6.00	6.00	5.80	5.65	5.65	5.60
4	80	7.00	6.90	6.90	6.70	6.55	6.40	6.30	6.10	6.10	6.10
4	75	6.60	6.50	6.40	6.30	6.20	6.10	6.00	6.00	6.00	5.80
4	77	6.60	6.30	6.00	6.00	5.90	5.70	5.70	5.70	5.70	5.70
Mean		6.86	6.69	6.53	6.40	6.29	6.19	6.10	6.01	5.96	5.89
Std. deviation		.18		.29		.29		.27		.24	
Std. error of mean		.03		.05		.05		.05		.04	

Table 49 . (Cont.)

Post-mortem time, hr		11	12	13	14	15	16	17	18	19	20
Treat. No.	Animal No.										
1	100	5.70	5.60	5.70	5.70	5.70	5.70	5.60	5.60	5.60	5.60
1	99	5.45	5.70	5.60	5.65	5.65	5.65	5.65	5.60	5.70	5.70
1	95	5.50	5.55	5.60	5.70	6.00	6.00	5.90	5.80	5.75	6.05
1	63	6.30	6.23	6.15	6.10	6.10	6.10	6.05	6.00	5.95	5.90
1	61	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70
1	70	5.85	5.80	5.85	5.80	5.80	5.75	5.75	5.75	5.75	5.70
1	78	5.65	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
1	73	5.70	5.70	5.70	5.70	5.70	5.65	5.65	5.60	5.60	5.60
1	71	6.05	6.00	6.00	6.00	5.85	5.75	5.75	5.70	5.70	5.70
2	97	5.65	5.70	5.50	5.60	5.70	5.70	5.70	5.60	5.60	5.60
2	180	5.50	5.50	5.50	5.50	5.50	5.60	5.60	5.60	5.60	5.60
2	181	5.60	5.65	5.60	5.70	5.70	5.60	5.75	5.70	5.80	5.70
2	59	5.90	5.90	5.90	5.85	5.80	5.80	5.80	5.80	5.80	5.80
2	60	6.10	6.10	6.00	5.90	6.00	5.80	5.80	5.80	5.85	5.85
2	69	5.90	5.90	5.90	5.80	5.80	5.75	5.75	5.70	5.70	5.70
2	82	6.20	6.10	6.00	6.00	5.95	5.90	5.90	5.80	5.80	5.80
2	79	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.70	5.65	5.65
2	72	6.00	6.00	5.90	5.90	5.85	5.80	5.75	5.70	5.70	5.70

Table 49 . (Cont.)

Post-mortem time, hr		11	12	13	14	15	16	17	18	19	20
Treat. No.	Animal No.										
3	98	5.60	5.60	5.60	5.60	5.75	5.85	6.00	5.90	5.90	5.75
3	96	5.60	5.60	5.60	5.60	5.65	5.60	5.65	5.65	5.50	6.00
3	159	5.80	5.80	5.65	5.80	5.70	5.60	5.65	5.50	5.55	5.50
3	62	6.10	6.10	6.00	6.00	6.00	5.90	5.85	5.80	5.85	5.80
3	65	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70
3	64	6.00	5.95	5.95	5.90	5.85	5.85	5.85	5.85	5.85	5.90
3	81	6.10	6.00	5.95	5.90	5.85	5.85	5.80	5.80	5.75	5.75
3	76	5.90	5.90	5.85	5.80	5.80	5.80	5.75	5.75	5.75	5.75
3	74	6.20	6.20	6.20	6.20	6.10	6.00	5.95	5.90	5.90	5.80
4	93	5.95	6.00	5.90	5.80	5.80	5.70	5.60	5.60	5.60	5.65
4	92	5.85	5.65	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
4	91	6.00	6.00	6.00	5.90	5.90	5.90	5.90	6.00	6.00	5.90
4	66	5.90	5.90	5.90	5.85	5.85	5.85	5.80	5.80	5.80	5.80
4	68	5.85	5.75	5.80	5.75	5.70	5.70	5.70	5.80	5.80	5.80
4	67	5.50	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
4	80	6.10	6.00	5.95	5.95	5.90	5.80	5.80	5.80	5.80	5.80
4	75	5.70	5.75	5.75	5.70	5.75	5.75	5.70	5.70	5.70	5.70
4	77	5.65	5.60	5.65	5.60	5.60	5.60	5.60	5.60	5.60	5.60
Mean		5.83	5.82	5.79	5.78	5.78	5.75	5.75	5.73	5.73	5.73
Std. deviation		.23		.19		.15		.12		.12	
Std. error of mean		.04		.03		.02		.02		.02	

Table 49 . (Cont.)

Post-mortem time, hr		21	22	23	24	28	32	36	40	44	48	192
Treat. No.	Animal No.											
1	100	5.60	5.60	5.70	5.50	5.70	5.60	5.50	5.50	5.50	5.60	5.60
1	99	5.75	5.80	5.80	5.80	6.00	5.80	5.80	5.70	5.80	5.80	5.55
1	95	5.80	5.80	6.00	6.00	6.00	5.95	5.90	5.95	6.00	6.00	5.60
1	63	5.90	5.90	5.90	5.90	5.90	5.80	5.85	5.75	5.70	5.90	5.80
1	61	5.70	5.70	5.70	5.70	5.60	5.60	5.60	5.60	5.60	5.60	5.55
1	70	5.70	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.60	5.60	5.60
1	78	5.55	5.55	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.50
1	73	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.50
1	71	5.65	5.65	5.65	5.65	5.60	5.60	5.60	5.60	5.60	5.60	5.55
2	97	5.60	5.60	5.60	5.55	5.60	5.50	5.55	5.50	5.50	5.50	5.70
2	180	5.60	5.60	5.50	5.50	6.00	5.70	5.70	5.70	6.00	6.00	5.65
2	181	5.70	5.70	5.70	5.60	5.50	5.60	5.70	5.60	5.70	5.75	5.70
2	59	5.80	5.80	5.70	5.80	5.75	5.75	5.70	5.70	5.70	5.70	5.60
2	60	5.85	5.80	5.80	5.80	5.80	5.80	5.70	5.65	5.65	5.65	5.55
2	69	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70
2	82	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.55
2	79	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.65	5.60
2	72	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.60	5.60	5.60

Table 49 . (Cont.)

Post-mortem time, hr		21	22	23	24	28	32	36	40	44	48	192
Treat. No.	Animal No.											
3	98	6.00	5.70	5.70	5.60	5.90	5.85	5.80	5.80	5.80	5.60	5.60
3	96	6.00	6.00	5.80	5.80	5.70	5.60	5.70	5.70	5.65	5.50	5.60
3	159	5.50	5.60	5.60	5.60	5.40	5.40	5.40	5.50	5.50	5.50	5.65
3	62	5.80	5.80	5.80	5.80	5.80	5.80	5.70	5.80	5.80	5.80	5.60
3	65	5.70	5.70	5.60	5.60	5.60	5.60	5.60	5.50	5.60	5.60	5.50
3	64	5.85	5.90	5.90	5.90	5.80	5.80	5.70	5.70	5.70	5.70	5.90
3	81	5.75	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.60
3	76	5.75	5.70	5.65	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
3	74	5.75	5.75	5.70	5.65	5.65	5.65	5.65	5.65	5.60	5.60	5.55
4	93	5.65	5.65	5.65	5.90	5.90	5.70	5.80	5.90	6.00	5.90	5.50
4	92	5.80	5.90	5.60	6.00	5.90	5.70	5.80	6.00	5.90	6.00	5.40
4	91	6.00	6.00	5.95	5.95	6.30	6.15	5.85	6.10	6.10	6.05	6.15
4	66	5.80	5.70	5.70	5.70	5.65	5.65	5.60	5.65	5.70	5.65	5.50
4	68	5.70	5.80	5.70	5.70	5.70	5.70	5.60	5.60	5.60	5.60	5.50
4	67	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
4	80	5.80	5.75	5.70	5.70	5.70	5.70	5.65	5.60	5.60	5.60	5.50
4	75	5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.75	5.70	5.70	5.55
4	77	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
Mean		5.73	5.72	5.70	5.71	5.73	5.69	5.67	5.68	5.69	5.69	5.60
Std. deviation		.12			.13			.11			.15	.13
Std. error of mean		.02			.02			.02			.03	.02

Table 50 . Percentage of total, bound and free moisture in raw steaks from L. dorsi muscle of 36 animals relative to post-mortem time.

Post-mortem time, hr		1			24			48			192		
Moisture, %		Total	Bound	Free	Total	Bound	Free	Total	Bound	Free	Total	Bound	Free
Treat. No.	Animal No.												
1	100	74.64	69.21	5.43	75.83	63.82	12.01	75.30	65.63	9.67	75.84	63.41	12.43
1	99	73.55	66.26	7.29	74.27	61.69	12.58	73.94	61.61	12.33	75.99	61.31	14.68
1	95	74.26	66.22	8.04	74.26	59.13	15.13	74.40	61.60	12.80	74.93	62.38	12.55
1	63	74.19	67.22	6.97	75.58	65.34	10.24	75.42	61.30	14.12	74.85	58.15	16.70
1	61	74.07	67.86	6.21	73.48	60.37	13.11	74.09	60.26	13.83	74.38	56.93	17.45
1	70	74.61	67.23	7.38	75.77	61.43	14.34	75.28	59.11	16.17	77.34	63.09	14.25
1	78	75.31	65.96	9.35	75.61	64.77	10.84	76.11	67.38	8.73	75.79	64.88	10.91
1	73	75.31	65.68	9.63	77.25	64.70	12.55	76.34	63.48	12.86	75.85	62.18	13.67
1	71	70.83	68.94	1.89	71.12	64.37	6.75	71.71	62.90	8.81	73.33	63.11	10.22
2	97	75.10	70.09	5.01	75.57	63.84	11.73	75.13	63.86	11.27	76.32	62.92	13.40
2	180	75.11	67.19	7.92	75.18	64.19	10.99	75.20	66.55	8.65	75.75	66.48	9.27
2	181	74.84	68.71	6.13	75.59	62.91	12.68	75.54	64.14	11.40	76.17	60.44	15.73
2	59	74.35	68.13	6.22	74.87	62.30	12.57	75.65	63.70	11.95	74.77	58.83	15.94
2	60	74.74	68.17	5.57	75.21	62.09	13.12	75.78	61.88	13.90	75.77	58.41	17.36
2	69	74.85	68.62	6.23	75.18	64.71	10.47	75.09	64.32	10.77	75.85	65.27	10.58
2	82	73.10	63.28	9.82	73.80	56.57	17.23	73.24	60.77	12.47	74.19	61.68	12.51
2	79	73.55	61.88	11.67	73.09	62.69	10.40	74.50	63.45	11.05	73.52	60.98	12.54
2	72	74.87	64.45	10.42	75.18	62.09	13.09	75.73	63.12	12.61	75.05	61.85	13.20

Table 50 . (Cont.)

Post-mortem time, hr		1			24			48			192		
Moisture, %		Total	Bound	Free	Total	Bound	Free	Total	Bound	Free	Total	Bound	Free
Treat. No.	Animal No.												
3	98	73.44	67.08	6.36	74.82	62.90	11.92	75.17	62.56	12.61	75.19	61.79	13.40
3	96	74.41	68.52	5.89	75.45	64.83	10.62	74.79	66.27	8.52	75.27	64.66	10.61
3	159	74.60	66.84	7.76	74.55	61.23	13.32	74.40	62.11	12.29	75.14	62.13	13.01
3	62	72.75	67.92	4.83	73.66	62.68	10.98	73.66	60.83	12.83	72.51	58.42	14.09
3	65	74.36	67.30	7.06	73.98	63.41	10.57	75.65	62.53	13.12	75.28	59.34	15.94
3	64	75.15	68.44	6.71	75.94	64.85	11.09	76.18	66.27	9.91	77.37	66.84	10.53
3	81	74.62	64.58	10.04	75.54	60.86	14.68	76.08	63.35	12.73	75.26	62.34	12.92
3	76	75.14	65.46	9.68	75.43	63.89	11.54	76.05	64.51	11.54	75.77	61.34	14.43
3	74	74.47	71.91	2.56	75.47	66.06	9.41	74.06	65.64	8.42	75.00	64.92	10.08
4	93	74.20	66.47	7.73	74.38	63.05	11.33	73.51	62.31	11.20	74.62	64.00	10.62
4	92	73.93	67.30	6.63	74.02	65.32	8.70	74.51	63.63	10.88	74.07	63.27	10.80
4	91	74.83	68.45	6.38	75.14	66.58	8.56	75.11	67.91	7.20	75.68	65.82	9.86
4	66	73.41	68.56	4.85	74.20	62.08	12.12	73.26	62.09	11.17	73.64	58.36	15.28
4	68	74.01	67.83	6.18	73.93	64.20	9.73	74.85	64.48	10.37	75.26	60.90	14.36
4	67	73.67	66.86	6.81	75.88	61.60	14.28	74.28	61.32	12.96	75.42	58.32	17.10
4	80	74.81	64.52	10.29	75.37	57.51	17.86	74.77	62.62	12.15	74.69	61.66	13.03
4	75	74.92	65.15	9.77	75.38	63.40	11.98	75.49	64.68	10.81	75.59	59.80	15.79
4	77	73.67	66.30	7.37	75.34	62.87	12.47	74.06	61.33	12.73	75.04	56.02	19.02
Mean		74.27	67.10	7.17	74.87	62.90	11.97	74.84	63.32	11.52	75.18	61.73	13.45
Std. deviation		.88	1.96	2.14	1.07	2.18	2.24	1.00	2.06	1.91	1.00	2.71	2.51
Std. error of mean		.15	.33	.36	.18	.36	.37	.17	.34	.32	.17	.45	.42

Table 51 . Cooking characteristics of L. dorsi steaks (broiled) of 36 animals relative to post-mortem time.

Post-mortem time, hr		1			24		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
1	100	34	22.67	3.78	8	34.55	4.37
1	99	32	26.11	3.76	9	32.07	4.89
1	95	32	25.64	3.50	4	29.19	4.73
1	63	34	21.25	3.44	17	28.90	4.66
1	61	33	38.22	3.78	12	28.41	4.55
1	70	32	24.77	4.21	8	30.62	5.94
1	78	29	22.92	2.67	13	25.83	4.17
1	73	33	24.19	3.25	17	28.57	4.15
1	71	33	25.00	2.76	9	25.12	3.91
2	97	33	27.00	4.01	3	33.33	5.43
2	180	33	22.13	2.37	7	37.61	4.99
2	181	31	23.03	3.03	16	35.15	5.20
2	59	31	23.33	2.87	16	34.58	4.75
2	60	30	16.99	3.09	14	28.87	4.71
2	69	33	25.23	3.94	11	29.44	4.82
2	82	34	24.15	4.27	10	24.23	5.15
2	79	37	19.48	3.35	20	27.01	3.67
2	72	36	20.50	4.25	10	29.93	1.68

Table 51 . (Cont.)

Post-mortem time, hr		1			24		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
3	98	32	27.05	4.11	11	26.28	4.17
3	96	32	21.36	3.98	4	34.18	5.61
3	159	33	25.00	4.17	17	31.25	5.00
3	62	31	26.50	3.95	4	33.71	6.32
3	65	30	25.62	3.38	11	28.70	4.28
3	64	33	25.11	2.83	18	24.73	5.22
3	81	33	21.67	3.20	4	20.77	5.19
3	76	33	25.37	3.31	12	28.50	4.67
3	74	32	18.78	3.76	12	30.26	5.90
4	93	32	20.74	2.41	6	28.87	4.38
4	92	32	33.96	3.21	8	34.19	7.82
4	91	32	26.25	3.44	14	29.11	4.78
4	66	32	28.02	5.17	4	35.87	5.66
4	68	29	25.51	3.81	14	26.94	4.68
4	67	32	24.52	4.21	4	33.33	5.56
4	80	31	25.11	3.43	4	33.19	5.09
4	75	34	20.11	3.16	4	35.71	5.36
4	77	36	28.80	4.02	11	30.95	5.80
Mean		32.47	24.50	3.55	10.17	30.28	4.92
Std. deviation		1.73	3.95	.60	4.87	3.83	.86
Std. error of mean		.29	.66	.10	.81	.64	.14

Table 51 . (Cont.)

Post-mortem time, hr		48			192		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
1	100	6	36.29	4.75	14	36.87	4.49
1	99	10	36.89	3.74	8	31.64	5.08
1	95	2	35.00	6.25	11	35.71	6.17
1	63	10	31.03	5.74	17	32.06	6.11
1	61	10	31.72	4.83	24	30.23	6.20
1	70	10	24.83	5.52	20	35.09	5.48
1	78	12	35.32	4.15	6	36.32	5.72
1	73	5	32.58	4.52	10	30.62	5.74
1	71	9	32.14	5.06	13	30.00	5.50
2	97	9	34.01	6.09	12	33.75	5.63
2	180	4	34.63	4.44	7	30.90	4.72
2	181	6	35.58	5.01	13	34.18	4.27
2	59	8	31.64	5.65	13	37.65	6.02
2	60	8	29.85	4.60	10	34.10	5.49
2	69	7	31.43	6.14	19	31.45	6.25
2	82	14	28.57	5.59	13	31.45	5.66
2	79	16	31.38	5.32	9	30.67	7.50
2	72	4	32.12	6.51	6	33.94	8.94

Table 51 . (Cont.)

Post-mortem time, hr		48			192		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
3	98	7	32.03	6.32	14	24.83	4.14
3	96	11	37.05	4.96	13	35.71	5.24
3	159	8	33.33	6.54	11	35.81	5.91
3	62	7	31.51	6.34	9	36.52	7.32
3	65	8	34.00	5.63	16	41.62	6.36
3	64	12	33.55	6.45	16	30.63	6.15
3	81	17	27.17	4.76	10	34.19	5.81
3	76	9	30.65	4.66	6	34.67	5.65
3	74	1	45.50	6.08	9	28.66	6.05
4	93	6	37.72	5.15	11	38.76	4.84
4	92	10	34.87	4.45	13	33.01	4.13
4	91	18	31.76	4.22	26	30.93	4.64
4	66	9	35.56	5.28	14	35.71	6.82
4	68	13	28.36	4.10	17	25.32	4.43
4	67	8	32.26	5.00	19	28.26	4.89
4	80	14	28.74	4.31	11	37.96	6.81
4	75	2	38.56	5.56	7	26.32	7.08
4	77	6	33.10	6.87	9	29.47	7.63
Mean		8.78	33.08	5.29	12.67	32.92	5.80
Std. deviation		4.02	3.70	.83	4.82	3.81	1.07
Std. error of mean		.67	.62	.14	.80	.64	.18

Table 52 . Cooking characteristics of L. dorsi steaks (deep fat fried) of 36 animals relative to post-mortem time.

Post-mortem time, hr		1			24		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
1	100	34	28.57	1.76	8	34.80	2.80
1	99	32	28.30	3.25	2	32.56	4.84
1	95	32	30.65	2.60	4	34.76	3.81
1	63	34	17.26	2.03	17	33.33	3.79
1	61	33	24.88	2.42	12	32.93	4.42
1	70	31	27.05	3.14	5	28.57	2.95
1	78	30	26.32	1.79	10	34.13	2.78
1	73	32	28.63	2.00	17	35.24	2.86
1	71	32	25.79	2.21	8	33.33	3.33
2	97	32	28.73	2.90	6	29.85	3.73
2	180	32	19.37	1.37	4	33.96	2.96
2	181	31	25.41	2.35	16	30.11	2.55
2	59	30	36.71	2.31	14	35.84	3.32
2	60	30	27.60	3.02	13	30.59	3.08
2	69	33	29.86	2.57	9	27.84	2.94
2	82	33	26.42	2.64	9	33.33	3.90
2	79	34	28.80	2.36	20	34.95	2.79
2	72	36	22.89	2.11	9	35.06	4.27

Table 52 . (Cont.)

Post-mortem time, hr		1			24		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
3	98	31	31.10	2.95	11	34.62	3.46
3	96	31	24.70	1.72	2	35.48	3.76
3	159	31	26.75	2.60	17	35.98	4.37
3	62	29	26.07	2.49	4	33.70	5.11
3	65	30	30.45	2.84	11	32.37	3.78
3	64	31	27.91	2.21	17	22.29	2.71
3	81	34	22.67	1.62	4	33.87	3.49
3	76	32	27.97	2.12	9	35.32	3.44
3	74	32	22.02	2.29	11	33.16	3.66
4	93	31	20.66	1.72	6	32.89	3.73
4	92	31	24.15	1.51	7	32.82	2.63
4	91	31	13.73	.98	10	24.76	1.99
4	66	32	27.84	2.81	4	34.83	4.73
4	68	29	27.31	2.10	14	34.10	2.63
4	67	32	32.03	2.81	4	36.47	4.41
4	80	31	27.04	2.25	3	33.99	3.61
4	75	33	24.55	2.69	3	37.28	4.14
4	77	32	29.13	2.55	11	20.57	2.47
Mean		31.78	26.37	2.31	9.19	32.55	3.48
Std. deviation		1.50	4.26	.52	5.01	3.77	.74
Std. error of mean		.25	.71	.09	.84	.63	.12

Table 52 . (Cont.)

Post-mortem time, hr		48			192		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
1	100	4	39.52	3.83	13	33.33	3.00
1	99	10	32.37	3.13	8	38.73	4.29
1	95	2	36.52	4.07	9	35.56	3.89
1	63	10	35.33	4.89	14	38.17	5.15
1	61	7	36.30	4.62	22	38.21	4.67
1	70	3	36.57	4.66	19	35.94	4.30
1	78	10	37.67	3.14	17	40.00	3.81
1	73	3	34.40	3.10	10	38.15	4.14
1	71	9	34.21	3.62	9	42.61	4.78
2	97	7	35.14	3.38	12	39.87	4.74
2	180	4	36.98	3.13	7	29.77	2.06
2	181	6	40.87	3.61	13	33.73	3.11
2	59	8	37.89	4.08	11	41.21	5.00
2	60	6	37.44	3.97	9	41.18	4.81
2	69	4	34.88	4.22	18	33.83	3.57
2	82	14	32.00	3.33	12	41.22	5.41
2	79	16	26.82	2.28	8	40.00	4.71
2	72	2	37.93	5.34	4	42.86	6.51

Table 52 . (Cont.)

Post-mortem time, hr		48			192		
		Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.	Init. internal steak temp., °C	Cooking loss, %	Cooking time, min/100g wt.
Treat. No.	Animal No.						
3	98	7	32.93	3.69	14	31.41	3.37
3	96	11	28.08	3.24	13	44.70	3.80
3	159	6	36.18	4.11	11	40.13	3.95
3	62	7	34.23	4.36	7	40.00	5.60
3	65	6	35.20	3.91	15	39.41	4.22
3	64	11	35.76	4.97	14	35.43	3.68
3	81	16	36.09	3.36	9	42.76	4.61
3	76	9	35.71	2.93	4	41.92	4.42
3	74	3	35.15	3.74	8	34.48	3.79
4	93	6	34.38	2.86	11	43.09	3.46
4	92	8	36.40	2.96	12	29.95	3.39
4	91	10	37.00	3.56	17	37.25	3.68
4	66	9	37.78	4.86	12	39.51	3.70
4	68	9	30.14	3.35	14	35.98	3.66
4	67	7	32.40	3.13	18	39.10	4.41
4	80	9	27.75	2.49	9	42.07	4.51
4	75	3	37.23	4.38	7	40.16	5.31
4	77	8	35.76	3.81	7	39.42	6.97
Mean		7.50	35.03	3.72	11.58	38.91	4.31
Std. deviation		3.54	3.12	.72	4.21	1.63	.97
Std. error of mean		.59	.52	.12	.70	.27	.16

Table 53 . Values for W-B shear and palatability characteristics of L. dorsi steaks (broiled) of 36 animals relative to post-mortem time.

Post-mortem time, hr		1				24			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
1	100	5.18	6.25	4.75	4.75	9.55	2.00	5.25	5.25
1	99	5.38	5.62	4.75	4.75	9.07	2.25	4.75	5.50
1	95	6.84	5.12	4.62	4.88	8.66	2.50	5.25	6.00
1	63	3.65	7.00	5.25	5.50	9.02	2.00	5.00	6.00
1	61	4.97	5.25	4.50	4.75	7.33	4.75	6.50	6.50
1	70	4.00	6.50	5.00	4.50	9.23	2.00	5.00	5.50
1	78	7.87	5.25	4.00	4.25	6.26	4.50	5.25	6.75
1	73	8.47	2.50	5.00	6.50	6.31	3.50	5.00	6.75
1	71	5.64	5.25	3.50	5.00	8.24	4.50	5.50	6.75
2	97	5.80	5.75	4.75	4.75	8.31	2.00	5.50	6.25
2	180	4.96	5.50	4.38	4.62	11.44	1.75	4.50	3.88
2	181	5.00	6.00	4.25	4.75	11.61	1.75	5.75	5.50
2	59	6.50	5.00	5.00	5.25	6.92	4.00	5.25	6.50
2	60	4.48	6.25	3.00	5.75	6.44	3.00	5.00	6.25
2	69	5.70	5.00	4.00	4.50	9.31	2.00	6.25	6.50
2	82	3.89	7.25	4.00	4.50	7.97	3.25	5.75	6.00
2	79	5.48	5.00	3.25	5.50	6.30	5.00	5.75	5.00
2	72	6.32	6.25	3.75	6.00	10.05	2.75	4.75	5.75

Table 53 . (Cont.)

Post-mortem time, hr		1				24			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
3	98	6.09	4.88	4.62	4.25	8.80	2.25	5.50	6.00
3	96	5.82	4.88	4.75	4.75	11.07	1.25	5.00	5.25
3	159	5.87	4.50	5.00	4.50	7.17	2.25	4.75	6.00
3	62	5.87	6.25	5.25	4.75	8.21	3.75	6.25	5.25
3	65	7.84	3.00	3.00	5.00	7.50	2.75	6.00	6.75
3	64	5.22	5.75	3.50	5.50	5.65	3.25	6.00	6.50
3	81	3.47	7.00	4.25	4.75	7.52	5.75	5.50	6.50
3	76	6.79	6.00	4.00	4.75	11.49	2.25	5.00	6.00
3	74	3.41	6.25	3.00	4.50	9.73	3.50	6.00	5.50
4	93	4.75	5.50	4.75	5.12	8.09	1.88	4.62	5.00
4	92	6.59	4.50	5.25	4.75	11.54	1.62	5.12	4.75
4	91	5.55	5.00	3.88	4.50	7.71	2.75	4.75	4.75
4	66	7.76	4.75	3.00	5.00	6.25	5.75	5.50	5.75
4	68	6.33	5.00	3.25	4.50	5.80	5.00	6.00	6.75
4	67	6.52	5.25	5.25	4.00	8.69	3.25	5.50	5.00
4	80	5.00	6.25	5.25	5.00	10.39	2.25	5.00	5.75
4	75	5.02	6.25	4.00	5.50	8.71	3.25	5.00	4.50
4	77	8.12	6.00	4.00	4.75	10.56	5.25	5.50	6.00

Table 53 . (Cont.)

Post-mortem time, hr		48				192			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
1	100	7.09	2.25	5.25	5.25	5.32	6.75	5.75	4.25
1	99	7.28	3.25	5.00	6.25	4.06	6.50	5.50	4.50
1	95	7.54	3.25	5.75	5.50	7.84	4.75	5.00	4.50
1	63	7.44	3.75	4.75	5.50	3.77	6.75	6.00	5.75
1	61	4.96	5.00	5.75	5.75	3.73	7.25	6.75	5.75
1	70	8.67	3.50	5.25	5.00	5.21	6.50	5.25	5.25
1	78	4.94	6.00	5.75	5.75	3.92	6.75	6.00	4.75
1	73	5.63	5.25	5.75	6.25	2.64	7.75	6.25	5.25
1	71	5.68	5.50	5.50	6.25	2.44	7.67	5.67	5.67
2	97	6.02	4.25	5.50	5.00	3.18	7.25	5.75	5.50
2	180	7.81	1.75	4.50	4.75	6.95	5.50	5.75	6.50
2	181	10.06	1.75	5.25	4.50	6.27	5.25	5.75	6.00
2	59	7.23	4.75	5.50	6.25	4.21	6.75	6.75	4.50
2	60	6.85	5.00	5.00	5.75	3.92	7.00	6.25	5.00
2	69	8.33	3.50	5.25	4.50	4.94	6.00	6.00	5.00
2	82	7.53	4.75	5.50	5.75	6.10	6.00	6.00	6.00
2	79	7.81	5.25	4.75	5.50	4.93	6.50	6.00	4.75
2	72	9.53	4.00	5.50	5.25	4.65	6.33	5.33	5.33

Table 53 . (Cont.)

Post-mortem time, hr		48				192			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
3	98	6.60	3.00	5.50	5.25	3.03	8.00	6.25	5.25
3	96	8.90	1.75	4.75	3.50	8.08	4.50	5.00	4.00
3	159	8.28	3.50	4.75	5.00	3.86	6.25	6.50	5.00
3	62	5.65	5.25	6.00	6.00	4.45	7.25	7.25	4.50
3	65	6.16	4.00	6.25	5.00	4.40	6.25	5.75	5.25
3	64	7.12	3.75	5.25	3.75	5.29	6.50	6.00	5.50
3	81	6.79	4.50	5.75	6.50	5.94	5.75	6.25	5.50
3	76	8.06	4.25	5.00	4.75	4.66	6.50	6.00	4.50
3	74	9.03	4.00	5.25	5.75	5.96	5.67	5.33	5.33
4	93	8.76	2.50	5.50	5.25	7.98	5.00	5.50	4.00
4	92	10.83	1.25	5.00	5.25	6.74	5.00	5.00	4.50
4	91	8.87	3.50	4.75	5.00	7.72	3.50	5.50	5.00
4	66	6.86	5.25	6.00	6.00	3.41	7.25	7.25	5.50
4	68	4.91	5.75	5.75	6.25	3.97	7.25	6.00	6.25
4	67	9.76	3.75	5.00	5.25	5.70	5.75	5.75	5.00
4	80	8.24	4.00	4.75	6.25	5.99	6.00	6.00	4.50
4	75	8.27	5.00	4.75	5.25	4.51	7.00	6.25	5.00
4	77	7.05	6.25	5.75	6.25	3.03	7.67	5.67	4.67

Table 54 . Values for W-B shear and palatability characteristics of L. dorsi steaks (deep fat fried) of 36 animals relative to post-mortem time.

Post-mortem time, hr		1				24			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
1	100	6.19	6.00	4.75	4.75	8.77	1.75	5.25	5.25
1	99	4.20	5.75	5.25	4.50	8.27	2.50	5.00	5.25
1	95	6.21	4.75	4.25	4.38	8.25	3.50	5.25	5.25
1	63	2.95	7.25	4.75	5.75	9.10	2.25	4.75	5.75
1	61	5.76	5.75	4.00	5.25	6.78	5.25	5.75	6.00
1	70	3.73	7.00	4.50	4.25	8.14	2.50	5.00	5.50
1	78	6.54	5.50	4.25	4.25	5.78	5.75	5.50	5.75
1	73	8.58	4.00	5.00	5.75	5.90	4.25	5.00	6.50
1	71	4.95	5.75	3.25	4.50	7.48	4.50	4.75	5.75
2	97	5.06	6.25	4.00	4.50	8.95	2.00	5.75	6.00
2	180	5.90	5.50	4.38	4.75	10.30	1.88	4.12	4.75
2	181	5.03	6.00	4.50	4.25	10.28	1.75	5.50	6.00
2	59	6.55	4.25	4.50	3.75	8.21	3.25	5.25	5.75
2	60	4.26	6.25	3.00	5.25	6.57	2.50	5.00	6.25
2	69	5.21	4.25	3.75	4.50	8.56	3.25	5.75	6.25
2	82	2.58	7.00	4.25	4.50	8.41	4.00	5.25	6.25
2	79	7.28	6.00	3.50	4.75	6.16	5.50	6.00	5.75
2	72	6.06	6.50	3.00	5.00	9.67	3.75	5.00	5.25

Table 54 . (Cont.)

Post-mortem time, hr		48				192			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
1	100	7.90	3.00	5.25	4.00	4.80	6.25	4.75	4.25
1	99	7.87	3.50	4.50	5.75	4.45	7.00	5.75	4.50
1	95	8.19	2.50	5.75	5.50	7.93	3.75	5.25	5.00
1	63	6.84	4.00	4.75	4.75	5.20	6.50	5.50	5.25
1	61	6.02	4.50	6.00	4.75	3.13	7.00	6.25	5.25
1	70	7.39	4.50	5.25	4.75	4.21	6.75	5.00	5.00
1	78	5.54	5.75	5.50	5.50	4.05	7.50	6.25	4.75
1	73	5.35	6.25	5.00	5.75	2.53	7.75	6.25	5.00
1	71	6.57	6.25	5.00	5.75	2.92	7.33	5.67	5.00
2	97	5.62	5.75	5.50	5.00	2.27	7.50	6.00	4.75
2	180	9.32	2.75	4.75	4.75	5.76	5.75	5.75	6.50
2	181	8.58	2.00	5.75	4.75	5.35	6.75	5.25	5.25
2	59	6.67	4.75	6.00	5.25	4.22	7.25	6.75	4.50
2	60	6.26	5.75	5.50	5.25	3.10	7.50	6.25	4.50
2	69	8.87	2.75	5.00	4.50	5.81	6.75	5.75	4.75
2	82	7.00	5.25	5.50	6.00	5.68	5.50	5.50	5.25
2	79	6.37	5.50	5.00	6.25	5.00	7.00	5.25	4.00
2	72	9.08	3.25	5.25	4.50	5.34	6.00	5.67	5.33

Table 54 . (Cont.)

Post-mortem time, hr		1				24			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
3	98	5.96	4.62	4.75	4.50	8.03	2.50	5.00	5.75
3	96	5.58	5.62	4.88	5.25	10.39	1.25	4.50	5.00
3	159	6.42	5.00	4.50	4.50	8.46	1.75	5.00	4.50
3	62	4.77	6.75	5.00	5.00	7.27	3.75	6.00	5.00
3	65	7.45	4.25	2.75	5.00	8.02	3.25	4.75	5.50
3	64	5.50	5.50	4.25	4.75	6.54	3.75	5.50	6.50
3	81	3.61	7.00	3.75	5.00	6.47	3.75	5.00	6.25
3	76	5.63	5.00	3.00	4.50	9.71	2.50	4.75	5.25
3	74	3.36	7.00	3.00	4.25	8.27	4.75	5.25	5.75
4	93	4.60	5.88	4.88	4.88	8.44	2.25	4.75	5.00
4	92	6.81	4.62	5.12	4.62	10.76	1.38	5.25	4.50
4	91	4.77	4.75	4.12	4.50	6.70	3.75	5.38	5.75
4	66	6.77	4.75	2.75	4.75	6.19	5.50	5.25	6.00
4	68	6.85	4.75	3.50	4.50	5.92	4.25	5.25	6.75
4	67	7.81	5.50	4.75	3.75	8.54	4.00	5.25	4.50
4	80	4.74	7.00	4.50	5.00	8.05	2.50	5.00	6.00
4	75	5.48	5.75	3.50	5.25	9.30	3.75	5.25	4.25
4	77	8.28	6.25	3.75	4.75	4.72	5.75	5.00	7.25

Table 54 . (Cont.)

Post-mortem time, hr		48				192			
		W-B shear kg	Panel	Flavor	Juiciness	W-B shear kg	Panel	Flavor	Juiciness
Treat. No.	Animal No.								
3	98	7.23	4.25	5.50	5.75	2.45	8.00	6.00	4.75
3	96	7.76	2.75	5.00	4.00	8.57	5.25	6.25	4.75
3	159	8.67	4.00	5.00	4.50	5.71	6.50	6.25	4.75
3	62	6.51	4.50	5.50	5.50	3.68	7.50	6.75	4.50
3	65	6.53	5.00	5.50	4.75	3.85	7.00	6.00	5.00
3	64	6.79	4.00	5.25	3.75	5.10	6.25	5.75	5.00
3	81	7.26	4.25	5.50	5.25	5.43	7.25	5.75	5.25
3	76	7.24	4.25	4.50	4.25	4.64	7.00	6.00	4.25
3	74	9.36	4.50	5.50	5.00	5.57	5.67	5.00	5.33
4	93	9.02	2.75	4.75	5.75	9.00	4.25	5.00	3.25
4	92	9.06	2.00	4.50	5.00	6.45	5.00	5.00	4.00
4	91	8.09	3.25	4.50	4.75	7.45	3.75	5.50	4.75
4	66	6.12	5.25	6.25	5.50	3.28	7.00	5.75	6.25
4	68	5.58	5.50	5.50	5.00	4.10	6.75	6.25	5.25
4	67	9.30	4.50	4.75	5.50	5.15	5.75	5.00	5.50
4	80	7.75	4.50	4.50	5.75	7.59	6.50	5.75	4.75
4	75	7.43	5.25	5.00	5.00	4.88	7.00	6.25	4.75
4	77	6.08	6.50	5.25	5.75	3.77	6.67	5.00	4.67

Table 55 . Tenderness rank of broiled L. dorsi steak as evaluated by W-B shear at 1 hr post-mortem.

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
1	73	8.47	2.50	6.31	3.50	5.63	5.25	2.64	7.75
2	77	8.12	6.00	10.56	5.25	7.05	6.25	3.03	7.67
3	78	7.87	5.25	6.26	4.50	4.94	6.00	3.92	6.75
4	65	7.84	3.00	7.50	2.75	6.16	4.00	4.40	6.25
5	66	7.76	4.75	6.25	5.75	6.86	5.25	3.41	7.25
6	95	6.84	5.12	8.66	2.50	7.54	3.25	7.84	4.75
7	76	6.79	6.00	11.49	2.25	8.06	4.25	4.66	6.50
8	92	6.59	4.50	11.54	1.62	10.83	1.25	6.74	5.00
9	67	6.52	5.25	8.69	3.25	9.76	3.75	5.70	5.75
10	59	6.50	5.00	6.92	4.00	7.24	4.75	4.21	6.75
11	68	6.33	5.00	5.80	5.00	4.91	5.75	3.97	7.25
12	72	6.32	6.25	10.05	2.75	9.53	4.00	4.65	6.33
13	98	6.09	4.88	8.80	2.25	6.60	3.00	3.03	8.00
14	159	5.87	4.50	7.17	2.25	8.28	3.50	3.86	6.25
15	62	5.87	6.25	8.21	3.75	5.65	5.25	4.45	7.25
16	96	5.82	4.88	11.07	1.25	8.90	1.75	8.08	4.50
17	97	5.80	5.75	8.31	2.00	6.02	4.25	3.18	7.25
18	69	5.70	5.00	9.31	2.00	8.33	3.50	4.94	6.00
Mean		6.73	4.99	8.49	3.15	7.35	4.17	4.60	6.51
Std. deviation		.42	.99	1.87	1.32	1.70	1.37	1.58	1.02
Std. error of mean		.29	.23	.44	.31	.40	.32	.37	.24

Table 55 . (Cont.)

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
19	71	5.64	5.25	8.24	4.50	5.68	5.50	2.44	7.67
20	91	5.55	5.00	7.71	2.75	8.87	3.50	7.72	3.50
21	79	5.48	5.00	6.30	5.00	7.81	5.25	4.93	6.50
22	99	5.38	5.62	9.07	2.25	7.28	3.25	4.06	6.50
23	64	5.22	5.75	5.65	3.25	7.12	3.75	5.29	6.50
24	100	5.18	6.25	9.55	2.00	7.09	2.25	5.32	6.75
25	75	5.02	6.25	8.71	3.25	8.27	5.00	4.51	7.00
26	80	5.00	6.25	10.39	2.25	8.24	4.00	5.99	6.00
27	181	5.00	6.00	11.61	1.75	10.06	1.75	6.27	5.25
28	61	4.97	5.25	7.33	4.75	4.96	5.00	3.73	7.25
29	180	4.96	5.50	11.44	1.75	7.81	1.75	6.95	5.50
30	93	4.75	5.50	8.09	1.88	8.76	2.50	7.98	5.00
31	60	4.48	6.25	6.44	3.00	6.85	5.00	3.92	7.00
32	70	4.00	6.50	9.23	2.00	8.67	3.50	5.21	6.50
33	82	3.89	7.25	7.97	3.25	7.53	4.75	6.10	6.00
34	63	3.65	7.00	9.02	2.00	7.44	3.75	3.77	6.75
35	81	3.47	7.00	7.52	5.75	6.79	4.50	5.94	5.75
36	74	3.41	6.25	9.73	3.50	9.03	4.00	5.96	5.67
Mean		4.73	5.99	8.56	3.05	7.68	3.83	5.34	6.17
Std. deviation		.73	.68	1.65	1.23	1.18	1.20	1.45	.98
Std. error of mean		.17	.16	.39	.29	.28	.28	.34	.23

Table 56 . Tenderness rank of broiled L. dorsi steak as evaluated by W-B shear at 24 hr post-mortem.

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
1	181	5.00	6.00	11.61	1.75	10.06	1.75	6.27	5.25
2	92	6.59	4.50	11.54	1.62	10.83	1.25	6.74	5.00
3	76	6.79	6.00	11.49	2.25	8.06	4.25	4.66	6.50
4	180	4.96	5.50	11.44	1.75	7.81	1.75	6.95	5.50
5	96	5.82	4.88	11.07	1.25	8.90	1.75	8.08	4.50
6	77	8.12	6.00	10.56	5.25	7.05	6.25	3.03	7.67
7	80	5.00	6.25	10.39	2.25	8.24	4.00	5.99	6.00
8	72	6.32	6.25	10.05	2.75	9.53	4.00	4.65	6.33
9	74	3.41	6.25	9.73	3.50	9.03	4.00	5.96	5.67
10	100	5.18	6.25	9.55	2.00	7.09	2.25	5.32	6.75
11	69	5.70	5.00	9.31	2.00	8.33	3.50	4.94	6.00
12	70	4.00	6.50	9.23	2.00	8.67	3.50	5.21	6.50
13	99	5.38	5.62	9.07	2.25	7.28	3.25	4.06	6.50
14	63	3.65	7.00	9.02	2.00	7.44	3.75	3.77	6.75
15	98	6.09	4.88	8.80	2.25	6.60	3.00	3.03	8.00
16	75	5.02	6.25	8.71	3.25	8.27	5.00	4.51	7.00
17	67	6.52	5.25	8.69	3.25	9.76	3.75	5.70	5.75
18	95	6.84	5.12	8.66	2.50	7.54	3.25	7.84	4.75
Mean		5.58	5.75	9.94	2.44	8.36	3.35	5.37	6.13
Std. deviation		1.21	.68	1.10	.92	1.16	1.26	1.47	.95
Std. error of mean		.28	.16	.26	.22	.27	.30	.35	.22

Table 56 . (Cont.)

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
19	97	5.80	5.75	8.31	2.00	6.02	4.25	3.18	7.25
20	71	5.64	5.25	8.24	4.50	5.68	5.50	2.44	7.67
21	62	5.87	6.25	8.21	3.75	5.65	5.25	4.45	7.25
22	93	4.75	5.50	8.09	1.88	8.76	2.50	7.98	5.00
23	82	3.89	7.25	7.97	3.25	7.53	4.75	6.10	6.00
24	91	5.55	5.00	7.71	2.75	8.87	3.50	7.72	3.50
25	81	3.47	7.00	7.52	5.75	6.79	4.50	5.94	5.75
26	65	7.84	3.00	7.50	2.75	6.16	4.00	4.40	6.25
27	61	4.97	5.25	7.33	4.75	4.96	5.00	3.73	7.25
28	159	5.87	4.50	7.17	2.25	8.28	3.50	3.86	6.25
29	59	6.50	5.00	6.92	4.00	7.23	4.75	4.21	6.75
30	60	4.48	6.25	6.44	3.00	6.85	5.00	3.92	7.00
31	73	8.47	2.50	6.31	3.50	5.63	5.25	2.64	7.75
32	79	5.48	5.00	6.30	5.00	7.81	5.25	4.93	6.50
33	78	7.87	5.25	6.26	4.50	4.94	6.00	3.92	6.75
34	66	7.76	4.75	6.25	5.75	6.86	5.25	3.41	7.25
35	68	6.33	5.00	5.80	5.00	4.91	5.75	3.97	7.25
36	64	5.22	5.75	5.65	3.25	7.12	3.75	5.29	6.50
Mean		5.88	5.24	7.11	3.76	6.67	4.65	4.56	6.55
Std. deviation		1.40	1.17	.89	1.22	1.27	.89	1.54	1.08
Std. error of mean		.33	.28	.21	.29	.30	.21	.36	.26

Table 57 . Tenderness rank of broiled L. dorsi steak as evaluated by W-B shear at 48 hr post-mortem.

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
1	92	6.59	4.50	11.54	1.62	10.83	1.25	6.74	5.00
2	181	5.00	6.00	11.61	1.75	10.06	1.75	6.27	5.25
3	67	6.52	5.25	8.69	3.25	9.76	3.75	5.70	5.75
4	72	6.32	6.25	10.05	2.75	9.53	4.00	4.65	6.33
5	74	3.41	6.25	9.73	3.50	9.03	4.00	5.96	5.67
6	96	5.82	4.88	11.07	1.25	8.90	1.75	8.08	4.50
7	91	5.55	5.00	7.71	2.75	8.87	3.50	7.72	3.50
8	93	4.75	5.50	8.09	1.88	8.76	2.50	7.98	5.00
9	70	4.00	6.50	9.23	2.00	8.67	3.50	5.21	6.50
10	69	5.70	5.00	9.31	2.00	8.33	3.50	4.94	6.00
11	159	5.87	4.50	7.17	2.25	8.28	3.50	3.86	6.25
12	75	5.02	6.25	8.71	3.25	8.27	5.00	4.51	7.00
13	80	5.00	6.25	10.39	2.25	8.24	4.00	5.99	6.00
14	76	6.79	6.00	11.49	2.25	8.06	4.25	4.66	6.50
15	180	4.96	5.50	11.44	1.75	7.81	1.75	6.95	5.50
16	79	5.48	5.00	6.30	5.00	7.81	5.25	4.93	6.50
17	95	6.84	5.12	8.66	2.50	7.54	3.25	7.84	4.75
18	82	3.89	7.25	7.97	3.25	7.53	4.75	6.10	6.00
Mean		5.42	5.61	9.40	2.51	8.68	3.40	6.01	5.67
Std. deviation		1.02	.76	1.63	.89	.89	1.17	1.32	.28
Std. error of mean		.24	.18	.38	.21	.21	.28	.31	.07

Table 57 . (Cont.)

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
19	63	3.65	7.00	9.02	2.00	7.44	3.75	3.77	6.75
20	99	5.38	5.62	9.07	2.25	7.28	3.25	4.06	6.50
21	59	6.50	5.00	6.92	4.00	7.23	4.75	4.21	6.75
22	64	5.22	5.75	5.65	3.25	7.12	3.75	5.29	6.50
23	100	5.18	6.25	9.55	2.00	7.09	2.25	5.32	6.75
24	77	8.12	6.00	10.56	5.25	7.05	6.25	3.03	7.67
25	66	7.76	4.75	6.25	5.75	6.86	5.25	3.41	7.25
26	60	4.48	6.25	6.44	3.00	6.85	5.00	3.92	7.00
27	81	3.47	7.00	7.52	5.75	6.79	4.50	5.94	5.75
28	98	6.09	4.88	8.80	2.25	6.60	3.30	3.03	8.00
29	65	7.84	3.00	7.50	2.75	6.16	4.00	4.40	6.25
30	97	5.80	5.75	8.31	2.00	6.02	4.25	3.18	7.25
31	71	5.64	5.25	8.24	4.50	5.68	5.50	2.44	7.67
32	62	5.87	6.25	8.21	3.75	5.65	5.25	4.45	7.25
33	73	8.47	2.50	6.31	3.50	5.63	5.25	2.64	7.75
34	61	4.97	5.25	7.33	4.75	4.96	5.00	3.73	7.25
35	78	7.87	5.25	6.26	4.50	4.94	6.00	3.92	6.75
36	68	6.33	5.00	5.80	5.00	4.91	5.75	3.97	7.25
Mean		6.04	5.38	7.65	3.68	6.35	4.60	3.93	7.02
Std. deviation		1.50	1.17	1.41	1.32	.87	1.09	.94	.58
Std. error of mean		.35	.28	.33	.31	.21	.26	.22	.14

Table 58 . Tenderness rank of broiled L. dorsi steak as evaluated by W-B shear at 192 hr post-mortem.

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
1	96	5.82	4.88	11.07	1.25	8.90	1.75	8.08	4.50
2	93	4.75	5.50	8.09	1.88	8.76	2.50	7.98	5.00
3	95	6.84	5.12	8.66	2.50	7.54	3.25	7.84	4.75
4	91	5.55	5.00	7.71	2.75	8.87	3.50	7.72	3.50
5	180	4.96	5.50	11.44	1.75	7.81	1.75	6.95	5.50
6	92	6.59	4.50	11.54	1.62	10.83	1.25	6.74	5.00
7	181	5.00	6.00	11.61	1.75	10.06	1.75	6.27	5.25
8	82	3.89	7.25	7.97	3.25	7.53	4.75	6.10	6.00
9	80	5.00	6.25	10.39	2.25	8.24	4.00	5.99	6.00
10	74	3.41	6.25	9.73	3.50	9.03	4.00	5.96	5.67
11	81	3.47	7.00	7.52	5.75	6.79	4.50	5.94	5.75
12	67	6.52	5.25	8.69	3.25	9.76	3.75	5.70	5.75
13	100	5.18	6.25	9.55	2.00	7.09	2.25	5.32	6.75
14	64	5.22	5.75	5.65	3.25	7.12	3.75	5.29	6.50
15	70	4.00	6.50	9.23	2.00	8.67	3.50	5.21	6.50
16	69	5.70	5.00	9.31	2.00	8.33	3.50	4.94	6.00
17	79	5.48	5.00	6.30	5.00	7.81	5.25	4.93	6.50
18	76	6.79	6.00	11.49	2.25	8.06	4.25	4.66	6.50
Mean		5.23	5.72	9.22	2.67	8.40	3.29	6.20	5.63
Std. deviation		1.09	1.26	1.82	1.18	1.08	1.16	1.12	.85
Std. error of mean		.26	.30	.43	.28	.26	.27	.26	.20

Table 58 . (Cont.)

Post-mortem time, hr		1		24		48		192	
Rank	Animal No.	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel	W-B shear, kg	Panel
19	72	6.32	6.25	10.05	2.75	9.53	4.00	4.65	6.33
20	75	5.02	6.25	8.71	3.25	8.27	5.00	4.51	7.00
21	62	5.87	6.25	8.21	3.75	5.65	5.25	4.45	7.25
22	65	7.84	3.00	7.50	2.75	6.16	4.00	4.40	6.25
23	59	6.50	5.00	6.92	4.00	7.23	4.75	4.21	6.75
24	99	5.38	5.62	9.07	2.25	7.28	3.25	4.06	6.50
25	68	6.33	5.00	5.80	5.00	4.91	5.75	3.97	7.25
26	60	4.48	6.25	6.44	3.00	6.85	5.00	3.92	7.00
27	78	7.87	5.25	6.26	4.50	4.94	6.00	3.92	6.75
28	159	5.87	4.50	7.17	2.25	8.28	3.50	3.86	6.25
29	63	3.65	7.00	9.02	2.00	7.44	3.75	3.77	6.75
30	61	4.97	5.25	7.33	4.75	4.96	5.00	3.73	7.25
31	66	7.76	4.75	6.25	5.75	6.86	5.25	3.41	7.25
32	97	5.80	5.75	8.31	2.00	6.02	4.25	3.18	7.25
33	98	6.09	4.88	8.80	2.25	6.60	3.00	3.03	8.00
34	77	8.12	6.00	10.56	5.25	7.05	6.25	3.03	7.67
35	73	8.47	2.50	6.31	3.50	5.63	5.25	2.64	7.75
36	71	5.64	5.25	8.24	4.50	5.68	5.50	2.44	7.67
Mean		6.22	5.26	7.83	3.53	6.63	4.71	3.73	7.05
Std. deviation		1.34	1.13	1.38	1.21	1.27	.96	.65	.53
Std. error of mean		.32	.27	.33	.29	.30	.23	.15	.13

Table 59 . Nitrogen concentration and ultraviolet absorbance of water soluble and buffer soluble protein extracts.

			Water soluble protein extracts			Buffer soluble protein extracts		
Treat. No.	Animal No.	Post-mortem time, hr	Nitrogen conc. (mg N/ml)	Ultraviolet absorbance		Nitrogen conc. (mg N/ml)	Ultraviolet absorbance	
				260 mμ	280 mμ		260 mμ	280 mμ
1	100	1	.214	.143	.105	.430	.268	.240
		24	.227	.155	.097	.398	.275	.222
		48	.216	.158	.098	.410	.250	.220
		192	.215	.152	.100	.422	.282	.242
1	99	1	.219	.146	.104	.417	.279	.249
		24	.220	.168	.121	.380	.234	.217
		48	.210	.140	.093	.409	.269	.232
		192	.216	.168	.118	.402	.192	.157
1	95	1	.205	.140	.092	.416	.275	.423
		24	.250	.265	.110	.445	.285	.240
		48	.230	.150	.123	.434	.260	.225
		192	.204	.152	.115	.378	.246	.190
1	63	1	.197	.190	.134	.441	.304	.257
		24	.205	.143	.086	.442	.274	.208
		48	.155	.132	.096	.432	.250	.244
		192	.211	.148	.101	.447	.274	.248
1	61	1	.227	.310	.286	.421	.470	.393
		24	.232	.285	.203	.409	.400	.345
		48	.208	.325	.241	.400	.445	.345
		192	.223	.127	.050	.383	.254	.167

Table 59 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Water soluble protein extracts			Buffer soluble protein extracts		
			Nitrogen conc. (mg N/ml)	Ultraviolet absorbance		Nitrogen conc. (mg N/ml)	Ultraviolet absorbance	
				260 mμ	280 mμ		260 mμ	280 mμ
2	97	1	.196	.133	.105	.328	.255	.232
		24	.186	.158	.110	.330	.260	.225
		48	.173	.152	.101	.332	.254	.230
		192	.176	.157	.100	.327	.318	.266
2	180	1	.288	.245	.160	.436	.182	.155
		24	.216	.213	.151	.414	.165	.136
		48	.205	.174	.117	.417	.150	.120
		192	.248	.154	.102	.402	.156	.128
2	181	1	.234	.061	.038	.404	.193	.167
		24	.223	.157	.110	.383	.257	.235
		48	.216	.152	.103	.408	.257	.215
		192	.227	.149	.101	.410	.237	.220
2	59	1	.205	.104	.030	.425	.282	.215
		24	.211	.146	.065	.419	.280	.212
		48	.220	.143	.064	.419	.274	.203
		192	.231	.128	.057	.425	.270	.198
2	60	1	.247	.168	.128	.420	.298	.260
		24	.220	.161	.115	.414	.305	.255
		48	.251	.155	.110	.432	.315	.263
		192	.241	.165	.118	.406	.283	.231

Table 59 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Water soluble protein extracts			Buffer soluble protein extracts		
			Nitrogen conc. (mg N/ml)	Ultraviolet absorbance		Nitrogen conc. (mg N/ml)	Ultraviolet absorbance	
				260 mμ	280 mμ		260 mμ	280 mμ
3	98	1	.210	.408	.338	.408	.840	.453
		24	.191	.172	.113	.390	.275	.225
		48	.202	.150	.096	.413	.307	.268
		192	.219	.168	.118	.408	.288	.235
3	96	1	.203	.268	.100	.426	.295	.242
		24	.232	.150	.108	.402	.238	.208
		48	.216	.157	.104	.422	.305	.250
		192	.216	.154	.095	.416	.262	.230
3	159	1	.216	.170	.120	.333	.271	.223
		24	.175	.152	.097	.334	.286	.250
		48	.177	.152	.103	.326	.276	.240
		192	.176	.163	.107	.320	.275	.226
3	62	1	.205	.173	.118	.425	.293	.223
		24	.228	.155	.114	.382	.260	.118
		48	.230	.165	.115	.392	.260	.187
		192	.210	.140	.055	.388	.248	.185
3	65	1	.235	.150	.088	.455	.336	.280
		24	.216	.155	.095	.433	.310	.254
		48	.209	.162	.104	.431	.318	.263
		192	.226	.148	.082	.416	.283	.228

Table 59 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Water soluble protein extracts			Buffer soluble protein extracts		
			Nitrogen conc. (mg N/ml)	Ultraviolet absorbance		Nitrogen conc. (mg N/ml)	Ultraviolet absorbance	
				260 mμ	280 mμ		260 mμ	280 mμ
4	93	1	.275	.260	.169	.434	.273	.240
		24	.300	.291	.196	.398	.250	.215
		48	.284	.258	.175	.404	.255	.220
		192	.298	.290	.188	.384	.240	.215
4	92	1	.297	.246	.162	.440	.281	.250
		24	.304	.260	.180	.382	.248	.212
		48	.204	.178	.116	.404	.260	.225
		192	.183	.168	.118	.433	.270	.238
4	91	1	.245	.205	.145	.446	.193	.156
		24	.299	.247	.165	.424	.175	.140
		48	.283	.235	.152	.426	.181	.148
		192	.307	.290	.173	.414	.160	.128
4	66	1	.176	.165	.110	.352	.232	.241
		24	.203	.175	.122	.333	.230	.200
		48	.171	.159	.115	.317	.225	.196
		192	.196	.182	.125	.334	.224	.187
4	68	1	.218	.162	.108	.482	.315	.262
		24	.233	.160	.115	.450	.278	.235
		48	.222	.168	.122	.412	.277	.232
		192	.237	.148	.090	.420	.295	.239

Table 60 . Nitrogen concentration in water soluble, buffer soluble and buffer insoluble fractions of the L. dorsi of 20 animals.

			Nitrogen concentration (mg N/g tissue)				Nitrogen concentration (% of total tissue N)		
Treat. No.	Animal No.	Post-mortem time, hr	In total tissue	In water extracts	In buffer extracts	In buffer insol. residue	In water extracts	In buffer extracts	In buffer insol. residue
1	100	1	37.77	8.90	16.07	16.40	25.56	42.55	43.42
		24	38.15	9.53	15.76	6.23	24.99	41.31	50.20
		48	36.97	9.03	16.07	19.14	24.43	43.47	51.77
		192	35.66	8.99	16.54	18.69	25.20	46.38	52.41
1	99	1	36.65	9.24	16.35	15.95	25.21	44.61	43.52
		24	35.03	9.24	15.05	17.37	26.38	42.96	49.59
		48	35.20	8.78	16.44	15.29	24.94	46.70	43.44
		192	34.41	9.03	15.84	15.81	26.24	46.03	45.95
1	95	1	34.78	8.61	16.64	17.56	24.76	47.84	50.49
		24	36.95	10.70	15.84	17.30	28.96	42.87	46.82
		48	36.01	9.80	16.41	17.40	27.21	45.57	48.32
		192	36.58	8.40	15.04	19.67	22.96	41.12	53.77
1	63	1	36.75	8.12	16.93	16.90	22.10	46.07	45.99
		24	36.09	8.57	16.97	15.83	23.75	47.02	43.86
		48	36.95	7.75	17.11	17.50	20.97	46.31	47.36
		192	36.27	8.69	17.79	17.05	23.96	49.05	47.01
1	61	1	36.84	9.44	16.33	15.50	25.62	44.33	42.07
		24	35.08	9.70	16.20	16.59	27.65	46.18	47.29
		48	35.48	8.65	15.76	16.08	24.38	44.42	45.32
		192	34.83	9.37	15.17	17.67	26.90	43.55	50.73

Table 60 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Nitrogen concentration (mg N/g tissue)				Nitrogen concentration (% of total tissue N)		
			In total tissue	In water extracts	In buffer extracts	In buffer insol. residue	In water extracts	In buffer extracts	In buffer insol. residue
2	97	1	33.29	9.78	16.39	14.54	29.38	49.23	43.68
		24	35.15	9.29	16.52	15.95	26.43	47.00	45.38
		48	36.01	8.66	16.60	16.60	24.05	46.10	46.10
		192	35.39	8.78	16.35	16.86	24.81	46.20	47.64
2	180	1	37.02	12.11	17.18	17.03	32.71	46.41	46.00
		24	36.77	8.92	16.73	17.80	24.26	45.50	48.41
		48	35.08	8.61	16.85	17.74	24.54	48.03	50.57
		192	37.46	10.42	16.24	20.90	27.82	43.35	55.79
2	181	1	36.51	9.83	16.32	16.13	26.92	44.70	44.18
		24	37.84	9.32	14.94	21.08	24.63	39.48	55.71
		48	36.69	9.07	15.83	16.88	24.72	43.15	46.01
		192	35.08	9.44	16.32	15.76	26.91	46.52	44.93
2	59	1	36.71	8.61	16.75	14.08	23.45	45.63	38.35
		24	36.49	8.99	16.59	17.09	24.64	45.46	46.83
		48	35.80	9.33	16.59	16.74	26.06	46.34	46.76
		192	36.39	9.66	17.00	16.92	26.55	46.72	46.50
2	60	1	35.99	10.37	16.46	16.75	28.81	45.73	46.54
		24	38.79	9.15	16.39	19.69	23.59	42.25	50.76
		48	34.69	10.44	17.11	16.90	30.10	49.32	48.72
		192	35.05	10.12	16.08	16.23	28.87	45.88	46.31

Table 60 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Nitrogen concentration (mg N/g tissue) In total tissue	In water extracts	In buffer extracts	In buffer insol. residue	Nitrogen concentration (% of total tissue N) In water extracts	In buffer extracts	In buffer insol. residue
3	98	1	36.61	7.94	16.32	17.40	21.69	44.58	47.53
		24	36.03	7.87	15.60	17.21	21.84	43.30	47.77
		48	35.75	8.40	16.35	14.82	23.50	45.73	41.45
		192	35.36	9.11	16.32	16.21	25.76	46.15	45.84
3	96	1	37.55	8.53	16.53	17.53	22.72	44.02	46.68
		24	38.55	9.74	15.92	18.96	25.27	41.30	49.18
		48	39.07	9.12	16.37	18.11	23.34	41.90	46.35
		192	39.01	9.07	16.31	19.79	23.25	41.81	50.73
3	159	1	36.36	10.80	16.67	15.65	29.70	45.85	43.04
		24	37.00	8.74	16.71	16.53	23.62	45.16	44.68
		48	34.94	8.86	16.28	16.58	25.36	46.59	47.45
		192	36.58	8.78	16.00	17.78	24.00	43.74	48.61
3	62	1	34.81	8.65	17.00	11.90	24.85	48.84	33.62
		24	34.88	9.58	15.36	13.58	27.47	44.04	38.93
		48	35.51	9.66	15.76	13.67	27.20	44.38	38.50
		192	35.44	8.78	15.52	13.90	24.77	43.79	39.22
3	65	1	37.84	9.73	17.84	16.44	25.71	47.15	43.45
		24	37.84	9.03	16.89	17.96	23.86	44.64	47.46
		48	38.05	8.69	16.81	17.71	22.84	44.18	46.54
		192	37.97	9.49	16.47	17.83	24.99	43.38	46.96

Table 60 . (Cont.)

Treat. No.	Animal No.	Post-mortem time, hr	Nitrogen concentration (mg N/g tissue)				Nitrogen concentration (% of total tissue N)		
			In total tissue	In water extracts	In buffer extracts	In buffer insol. residue	In water extracts	In buffer extracts	In buffer insol. residue
4	93	1	39.03	11.47	17.19	17.77	29.39	44.04	45.53
		24	38.30	12.44	15.76	18.75	32.48	41.15	48.96
		48	37.77	11.82	15.84	17.66	31.29	41.94	46.76
		192	36.09	12.49	15.13	20.32	34.61	41.92	56.30
4	92	1	39.87	11.88	17.25	16.51	29.80	43.27	41.41
		24	37.71	12.77	15.05	19.17	33.86	39.91	50.84
		48	39.00	8.73	16.00	18.71	22.38	41.03	47.97
		192	38.27	7.72	17.15	20.74	20.17	44.81	54.19
4	91	1	36.04	10.69	17.66	18.25	29.66	49.00	50.64
		24	37.11	12.38	16.88	18.27	33.36	45.49	49.23
		48	35.71	11.75	16.87	16.63	32.90	47.24	46.57
		192	36.97	12.63	16.56	17.23	34.16	44.79	46.61
4	66	1	36.01	8.82	17.60	14.47	24.49	48.88	40.18
		24	36.82	10.16	16.63	16.82	27.59	45.17	45.68
		48	36.05	8.57	15.84	16.25	23.77	43.94	45.08
		192	36.46	9.79	16.72	15.61	26.85	45.86	42.81
4	68	1	38.04	9.16	19.67	16.24	24.08	51.71	42.69
		24	37.44	9.74	17.82	16.88	25.81	47.22	44.73
		48	37.66	9.32	16.32	17.20	24.75	43.34	45.55
		192	36.73	9.86	16.46	16.30	26.84	44.81	44.38

Table 61 . Viscosity of water and buffer soluble protein extracts of the L. dorsi muscle of 20 animals.

		Viscosity in cps. for water soluble protein extracts				Viscosity in cps. for buffer soluble protein extracts			
Post-mortem time, hr		1	24	48	192	1	24	48	192
Treat. No.	Animal No.								
1	100	1.230	1.177	1.138	1.043	1.363	1.278	1.323	1.160
1	99	1.168	1.233	1.147	1.105	1.287	1.319	1.409	1.315
1	95	1.142	1.263	1.159	1.265	1.303	1.436	1.436	1.291
1	63	1.065	1.164	1.247	1.228	1.348	1.252	1.287	1.599
1	61	1.048	1.149	1.051	1.087	1.280	1.300	1.281	1.186
2	97	1.165	1.057	1.171	1.133	1.229	1.355	1.325	1.307
2	180	1.153	1.178	1.220	1.149	1.383	1.245	1.274	1.283
2	181	1.142	1.181	1.137	1.126	1.240	1.323	1.263	1.348
2	59	1.138	1.184	1.037	1.138	1.285	1.221	1.305	1.281
2	60	1.178	1.058	1.090	1.126	1.445	1.412	1.360	1.337
3	98	1.154	1.154	1.208	1.146	1.359	1.299	1.364	1.286
3	96	1.161	1.114	1.112	1.151	1.391	1.253	1.354	1.309
3	159	1.155	1.150	1.107	1.214	1.200	1.427	1.209	1.316
3	62	1.137	1.160	1.023	1.165	1.335	1.283	1.297	1.191
3	65	1.106	1.222	1.208	1.175	1.446	1.316	1.226	1.286
4	93	1.166	1.201	1.171	1.175	1.395	1.250	1.328	1.263
4	92	1.228	1.157	1.138	1.155	1.291	1.374	1.416	1.295
4	91	1.074	1.156	1.230	1.196	1.450	1.218	1.307	1.298
4	66	1.117	1.214	1.078	1.164	1.417	1.411	1.155	1.416
4	68	1.220	1.183	1.134	1.196	1.312	1.245	1.360	1.237

Table 62 . Number of electrophoretic bands obtained by starch gel electrophoresis of water and buffer soluble protein extracts of the L. dorsi of 20 animals.

			Water soluble protein extracts						Buffer soluble protein extracts					
			Zone A				Zone B		Zone A				Zone B	
Treat. No.	Animal No.	Post-mortem time, hr	I	II	III	Total A	Total B	Total A + B	I	II	III	Total A	Total B	Total A + B
1	100	1	2	4	4	10	1	11	2	4	4	10	3	13
		24	2	4	5	11	1	12	2	4	4	10	3	13
		48	2	4	5	11	1	12	2	4	4	10	3	13
		192	2	4	4	10	1	11	2	4	4	10	3	13
1	99	1	2	3	3	8	2	10	2	4	3	9	4	13
		24	2	3	3	8	2	10	2	4	4	10	4	14
		48	2	3	3	8	2	10	2	4	4	10	4	14
		192	2	3	3	8	2	10	2	4	3	9	4	13
1	95	1	2	3	4	9	2	11	2	3	2	7	2	9
		24	2	3	4	9	2	11	2	3	3	8	2	10
		48	2	3	4	9	2	11	2	3	3	8	2	10
		192	2	3	2	7	2	9	2	2	2	6	2	8
1	63	1	2	3	5	10	2	12	2	4	3	9	2	11
		24	2	3	6	11	2	13	2	4	3	9	2	11
		48	2	3	6	11	2	13	2	4	3	9	2	11
		192	2	3	5	10	2	12	2	4	3	9	2	11
1	61	1	2	3	3	8	2	10	2	3	3	8	2	10
		24	2	3	3	8	2	10	2	3	3	8	2	10
		48	2	3	3	8	2	10	2	3	3	8	2	10
		192	2	3	3	8	2	10	2	3	3	8	2	10

Table 62 . (Cont.)

			Water soluble protein extracts						Buffer soluble protein extracts					
			Zone A				Zone B		Zone A				Zone B	
Treat. No.	Animal No.	Post-mortem time, hr	I	II	III	Total A	Total B	Total A + B	I	II	III	Total A	Total B	Total A + B
2	97	1	2	4	3	9	3	12	2	4	5	11	3	14
		24	2	4	4	10	3	13	2	4	5	11	3	14
		48	2	4	4	10	3	13	2	4	5	11	3	14
		192	2	4	3	9	3	12	2	4	5	11	3	14
2	180	1	2	5	2	9	2	11	2	2	2	6	2	8
		24	2	5	2	9	2	11	2	2	2	6	1	7
		48	2	5	2	9	2	11	2	2	2	6	1	7
		192	2	5	2	9	2	11	2	2	2	6	2	8
2	181	1	2	3	4	9	3	12	2	4	2	8	4	12
		24	2	3	5	10	3	13	2	4	2	8	4	12
		48	2	3	5	10	3	13	2	4	2	8	4	12
		192	2	3	5	10	3	13	2	4	2	8	4	12
2	59	1	2	3	4	9	2	11	2	4	2	8	3	11
		24	2	3	5	10	2	12	2	4	2	8	3	11
		48	2	3	5	10	2	12	2	4	2	8	3	11
		192	2	3	5	10	2	12	2	4	2	8	3	11
2	60	1	2	4	2	8	1	9	2	3	2	7	2	9
		24	2	4	2	8	1	9	2	3	2	7	2	9
		48	2	4	2	8	1	9	2	3	2	7	2	9
		192	2	4	2	8	1	9	2	3	2	7	2	9

Table 62 . (Cont.)

			Water soluble protein extracts						Buffer soluble protein extracts					
			Zone A				Zone B		Zone A				Zone B	
Treat. No.	Animal No.	Post-mortem time, hr	I	II	III	Total A	Total B	Total A + B	I	II	III	Total A	Total B	Total A + B
3	98	1	2	3	4	9	2	11	2	4	4	10	3	13
		24	2	3	4	9	2	11	2	4	4	10	3	13
		48	1	3	4	8	2	10	2	4	4	10	3	13
		192	1	3	4	8	2	10	2	4	4	10	3	13
3	96	1	2	3	4	9	3	12	2	4	3	9	4	13
		24	2	3	5	10	3	13	2	4	3	9	4	13
		48	2	3	5	10	3	13	2	4	3	9	4	13
		192	2	3	5	10	3	13	2	4	3	9	4	13
3	159	1	2	3	3	8	2	10	2	4	3	9	2	11
		24	2	3	4	9	2	11	2	4	4	10	2	12
		48	2	3	4	9	2	11	2	4	4	10	2	12
		192	2	3	3	8	2	10	2	4	4	10	2	12
3	62	1	2	3	4	9	3	12	2	4	1	7	2	9
		24	2	3	4	9	3	12	2	4	1	7	2	9
		48	2	3	4	9	3	12	2	4	1	7	2	9
		192	2	2	4	8	3	11	2	4	1	7	2	9
3	65	1	2	3	4	9	2	11	2	3	2	7	2	9
		24	2	3	4	9	2	11	2	3	2	7	2	9
		48	2	3	4	9	2	11	2	3	2	7	2	9
		192	2	3	4	9	2	11	2	3	2	7	2	9

Table 62 . (Cont.)

			Water soluble protein extracts						Buffer soluble protein extracts					
			Zone A				Zone B		Zone A				Zone B	
Treat. No.	Animal No.	Post-mortem time, hr	I	II	III	Total A	Total B	Total A + B	I	II	III	Total A	Total B	Total A + B
4	93	1	2	3	4	9	2	11	2	4	3	9	3	12
		24	2	3	4	9	2	11	2	3	4	9	2	11
		48	2	3	4	9	3	12	2	3	4	9	2	11
		192	2	3	3	8	3	11	2	2	4	8	2	10
4	92	1	2	3	4	9	3	12	2	3	1	6	2	8
		24	2	3	4	9	3	12	2	3	1	6	2	8
		48	2	3	4	9	3	12	2	3	1	6	2	8
		192	2	3	4	9	3	12	2	3	1	6	2	8
4	91	1	2	5	3	10	2	12	2	4	3	9	3	12
		24	2	3	3	8	1	9	2	4	3	7	3	10
		48	2	3	3	8	1	9	2	4	2	8	1	9
		192	2	2	4	8	1	9	2	4	2	8	2	10
4	66	1	2	3	4	9	3	12	2	4	1	7	2	9
		24	2	3	4	9	3	12	2	4	1	7	2	9
		48	2	3	4	9	3	12	2	4	1	7	2	9
		192	2	3	4	9	3	12	2	4	1	7	2	9
4	68	1	2	3	4	9	2	11	2	4	3	9	3	12
		24	2	3	5	10	2	12	2	4	3	9	3	12
		48	2	3	5	10	2	12	2	4	3	9	3	12
		192	2	3	4	9	2	11	2	4	3	9	3	12

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This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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