THE PALATABILITY OF CERTAIN BEEF MUSCLES COOKED IN DEEP FAT TO THREE DEGREES OF DONENESS

by

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INTRODUCTION

There is a need for more information regarding the palatability of different parts of the beef carcass that have been cooked to several degrees of doneness. In general, an increase in the internal temperature to which meat is cooked decreases the juiciness of the meat. This may be accounted for by a loss of moisture through evaporation and binding of water to the protein during the cooking process. Crocker (1948) reported that the "meaty flavor" of beef increased with cooking up to three hours, then decreased with longer cooking.

Generally, it is believed that muscle fibers become less tender as the protoplasmic proteins coagulate, whereas the collagenous connective tissue is softened and partially hydrolyzed with extended heating. Under certain conditions the changes in the connective tissue during cooking may increase the tenderness of the cooked meat more than the coagulation of muscle fiber proteins decreases tenderness. Satorius and Child (1938a) studied the effect of the degree of cooking on the tenderness of the semitendinosus muscle. They found that the shear values and the diameter of the muscle fibers decreased as the internal temperature of the muscle increased to 67°C., whereas the shear values increased and the diameter of the muscle fibers did not change between 67° and 75°C.

In view of the limited data relative to the effect of degree of doneness on the palatability of beef, it seemed worthwhile to design a study in which tender and less tender muscles were cooked rare, medium- and well-done. Therefore, in the study reported here, organoleptic and physical tests were used to evaluate the palatability of certain muscles cooked in deep fat to internal temperatures of 55°, 70° and 85°C.

The work for this thesis is a part of a larger study in which histological and chemical studies, as well as organoleptic and physical tests, will be employed to evaluate the results of the degree of cooking on the beef used in this study and on corresponding muscles from other animals which are roasted in the oven.

REVIEW OF LITERATURE

Composition and Structure of Muscle

Gross Structure. Maximow and Bloom (1952) reported that the skeletal muscle of mammals consists of striated muscular tissue and is composed of long, cylindrical muscle fibers or cells. These cells contain several nuclei that are elliptical in shape, and increase in number with the length of the fiber. The fibers may extend the length of a muscle with both ends terminating in tendons or both ends may terminate within the muscle. The muscle fibers are encased in a thin structureless membrane, the sarcolemma, and are held together in bundles or fasciculi by the endomysium connective tissue. The bundles, in turn, are held together by the perimysium and the whole muscle is surrounded by a heavy muscle sheath of connective tissue called the epimysium.

Composition and Structure of Muscle Fibers. Lowe (1955) cited the work of Smith (1937-1938) who listed the principal soluble proteins, i.e., the intracellular proteins, as being myosin, myogen, globulin X and myoalbumin. In 1948, Bailey reported that another protein, tropomyosin, had been isolated from minced muscle that was thought to be a prototype of myosin, or even one of the units from which myosin filaments are elaborated. Myosin itself has been studied rather extensively and is now believed to be a system rather than one protein.

Several studies were described by Szent-Gyorgyi (1951) in which myosin obtained by short extraction had a relatively low viscosity, whereas myosin obtained by extended extraction had a rather high viscosity. The latter proved to be a combination of a second protein, actin, with myosin thus forming the highly viscous actomyosin that is responsible for muscle contraction. He believed that myosin is a contractile protein that in itself is an enzyme associated with adenosine triphosphatase (ATP-ase) activity. Szent-Gyorgyi pointed out that other workers have found this difficult to believe and so have tried unsuccessfully to separate an enzyme from myosin. Actin is a reversible protein, changing back and forth from the fibrous to the globular form during muscle contraction.

The characteristics of other muscle constituents such as water, inorganic salts, muscle pigments, nitrogenous and non-nitrogenous extractives and enzymes are comprehensively reviewed by Lowe (1955).

According to Szent-Gyorgyi (1951) the muscle fiber, encased in the sarcolemma, contains cell nuclei surrounded by liquid sarcoplasm. Maximow and Bloom (1952) reported that the sarcoplasm may contain fat droplets, pigment, lipoid granules and glycogen. It was stated by Szent-Gyorgyi (1951) that although the fibers have a longitudinal striation, they also have a more definite cross striation. Across the fiber axis are regularly spaced thin Z-membranes about 0.002 millimeters apart that divide the fiber into disc-like partitions or sarcomers. Under the microscope the material in the fiber appears lighter on either side of the Z-membrane, but appears denser and darker in the middle of the sarcomere. When viewed with polarized light, however, the reverse is true. The material around the Z-membrane is designated as the I or J band, since it is isotropic; and the material in the center is designated as A or Q, since it is anistropic. A small loose thin membrane also is noticeable in the middle of the A band and is called the M membrane.

The contractile matter in the sarcolemma breaks up easily into thin columns, parallel to the longitudinal axis, which have been called fibrils. Hall et al. (1946) described these myofibrils as being composed of bundles of myosin filaments that extended continuously throughout the isotropic and anistropic bands. However, Szent-Gyorgyi (1951) pointed out that fibrils are artifacts caused by chemical or mechanical treatment outside the body, and they do not appear in intact muscle. He stated that since this material has been found by electron microscope, to have a three-dimensional structure, it should be called a liquid crystalline substance. Liquid crystals usually contain elongated particles held together by their dipole forces by side-to-side and end-to-end association, the association being stronger in the direction of the longer axis. However, Szent-Gyorgyi (1951) thought that the filaments observed by Hall et al. (1946) were the same monomolecular threads he obtained when muscle fiber was broken down in the Waring-Blendor. Therefore, he believed that there are no filaments or fibrils as such, only remnants of a disintegrated three-dimensional structure.

Composition and Structure of Connective Tissue. Connective tissue serves as a soft skeleton to support other tissues and the organs of an animal body. It may take several forms such as tendons, ligaments and coverings for muscles and muscle fibers. Basically it consists of three components, collagen, elastin, and an amorphorus ground substance. The connective tissue designated as collagenous is principally collagen, but may contain some of the other two components. The same is true for elastic tissue.

According to Maximow and Bloom (1952), the fibers in the loose collagenous tissues run in all directions. They may be straight or wavy, and consist of fibrils grouped parallel to each other in bundles. Although the fibers branch considerably, the fibrils do not. The cross striated fibrils contain long polypeptide chains that run parallel to the fibril axis. Although collagenous fibers are not elastic, they are quite flexible. When collected into dense, longitudinally striated bundles, the collagenous tissue appears white, and thus is called white fibrous connective tissue.

It was reported by Maximow and Bloom (1952) that the elastic connective tissue fibers are homogenous instead of fibrillar and are thinner than collagenous fibers. The main constituent of elastic fibers is elastin, which is an albuminoid. The elastic fibers run in various directions and branch freely, and are straight when in a natural position, but when teased onto a slide may appear wavy or spiral. When massed together, this connective tissue appears yellowish in color and is called yellow connective tissue. This tissue stretches easily.

The collagenous and elastic connective tissue fibers are embedded in a homogenous material or ground substance which varies from a fluid to a gel-like consistency. It reacts similar to a polysaccharide-containing protein or glycoprotein.

Factors Affecting Tenderness of Muscle

Many factors affect the tenderness of beef, and possibly many of them are interrelated. The effect of these factors and their interrelationships on the tenderness of meat are not fully understood.

Breed, Age, Sex and Grade. Husaini et al. (1950) studied the effect of breed and grade on the tenderness of beef. Ten Hereford and 10 Holstein steers about two and one-half years of age, were fed identical rations for one year prior to slaughter. The tenderness of the meat from these carcasses was tested at three and at 15 days post mortem. No difference in tenderness was found that could be attributed to breed or grade. For the most part, the Holstein carcasses graded U. S. Utility and the Hereford carcasses High Commercial. They found no correlation between tenderness and carcass grade or marbling. They thought that this was due to the uniformity of the test cattle.

When animals of various ages of the Shorthorn breed were tested for tenderness by Hiner et al. (1955), the more mature animals were rated less tender because of the presence of more connective tissue. This result supported previous work done by Hiner and Hankins (1950) on the effect of age on tenderness. The effect of connective tissue is a factor that will be discussed in more detail later.

With animals varying considerably in market grades, Husaini et al. (1950) found a low but significant correlation between marbling, which is a factor considered in carcass grading, and tenderness. Paul and Bratzler (1955) compared the tenderness of the longissimus dorsi muscle from U. S. Prime, Good and Commercial grades of beef animals, and found that the Prime grade was the most tender. However, an increase in cold storage time or aging tended to minimize the differences. Griswold (1955) obtained higher palatability scores for U. S. Prime than for U. S. Commercial grade when top and bottom round steaks were braised, but there were larger differences among animals within a grade than there were between these grades. Harrison et al. (1949) also found tenderness to be related to grade, the higher the grade the more tender the meat.

Brady (1937) fed six yearling steers and seven mature Holstein cows a standard ration for 180 days. Except for two steers which graded high medium, all carcasses graded good in their respective classes. He compared the relative tenderness of meat from the steers and cows, using muscles from the round and loin. The average Warner-Bratzler shear value for the steer muscles was 17.8±1.2 pounds and for the cows was 28.4±1.2 pounds. Similarly, it was reported by Cline et al. (1932) that cows were graded lower in tenderness than heifers or steers.

Muscle Fiber Diameter. According to Hiner et al. (1955) the greater the fiber diameter the less tender the meat. They observed that muscles that were exercised or worked the most contained the largest fibers. As the animals matured the muscle fiber diameter increased and tenderness decreased. This work was in agreement with that done by Brady (1937) in which he found a significant difference in the diameter of muscle fibers from cows and steers, from fresh and aged meat and among the muscles studied. This worker concluded that texture is an indication of tenderness, the finer the texture the more tender the meat. According to Ramsbottom et al. (1945), muscle fiber diameter was much larger in the superficial pectoral, a tough muscle, than in the psoas major, a tender muscle.

Holding or Ripening. Most workers seem to agree that holding or ripening tenderizes beef, but they do not all agree as to the factors involved or the processes that take place during ripening.

Harrison et al. (1949) aged four paired muscles from each of four animals at 35°F. for 1, 2, 5, 10, 20 and 30 days prior to cooking. Two animals graded U. S. Good (yearling steers), one graded U. S. Commercial (large 14-month-old steer) and one graded U. S. Cutter (an eight-year-old dairy cow). The psoas major, longissimus dorsi, semitendinosus and semimembranosus muscles were studied. The average tenderness scores for all cooked roasts indicated a gradual increase in tenderness as the aging period progressed. The greatest increase in tenderness occurred during the first 10 days of storage except for the muscles from one yearling steer. However, after 30 days of storage, the tenderness of this steer carcass was almost equal to that of the other animals. When the muscles were considered separately, the increase in tenderness with aging was not always linear. The muscles from the oldest animal, the eight-year-old dairy cow, tenderized more slowly than the muscles from the large 14-month-old steer.

When paired longissimus dorsi muscles were kept in cold storage by Paul and Bratzler (1955), steaks cut from the carcasses held for seven days were more tender than those from carcasses held for two days. Any handling of the muscles, such as removal from the carcass or cutting, interfered with the tenderizing and resulted in less tender steaks than those aged without handling or cutting. These results are in agreement with work done by Ramsbottom and Strandine (1949) in which loins boned prior to chilling were less tender than those not so treated. Beef chilled with the bone in was still more tender by the 12th day than beef boned before chilling. These workers theorized that this effect was probably due, in part, to the chemical and physical changes brought about by stimulation of muscle and nerve cells caused by cutting the muscle shortly after slaughter. A gradual softening and loosening of fiber bundles was noticeable by the 12th day, and it was noted that these changes occurred earlier in U. S. Good than in U. S. Utility grades of beef.

In a study in which Husaini et al. (1950) used 20 beef carcasses, the meat was tested after three and 15 days of holding. They reported a very significant correlation between the increases in tenderness and myoglobin concentration between three and 15 days. The correlation coefficient for these factors was 0.55, and appeared very significant, because with 17 degrees of freedom the correlation coefficients at the one and five percent levels were 0.57 and 0.46, respectively. They concluded that muscle plasma and connective tissue were closely related to the tenderizing effect of cold storage holding.

Griswold and Wharton (1941) studied the effect of several storage times and temperatures on the palatability of beef. They compared storage at 36°F. for nine and 37 days, storage at 60°F. for 48 hours with and without ultra violet light, and storage at 36°F. without irradiation and at 60°F. with irradiation for the same length of time. There were small differences in tenderness that were attributable to these treatments except that the meat held at 60°F. with irradiation was more tender than that held at 36°F. without irradiation. Other differences noted were that the meat held for 37 days had a stronger flavor and aroma, but was less juicy than that held for nine days at the same temperature, and that meat held at 60°F. for 48 hours with ultra violet light was more desirable in odor and appearance than that held at the same temperature without irradiation.

Freezing. There seems to be considerable difference in the results of studies relative to the effect of freezing and frozen storage on tenderness.

Hankins and Hiner (1940) demonstrated that freezing tenderized meat. They cut paired steaks from beef short loins that were aged five days at 34°F. and froze one of each pair. The internal temperature of some of the steaks was lowered to +20°F., that of some to -10°F. and that of others to -40°F. The other one of each pair was cooked in a 392°F. oven to an internal temperature of 136°F. As soon as the frozen steaks reached the desired temperature, they were allowed to thaw in a room maintained at 45°F., and then cooked in the same manner as the controls. As measured by the Warner-Bratzler shearing apparatus, the steaks that had been frozen were more tender than the unfrozen steaks. The steaks with internal temperatures of -10° and -40°F. were significantly more tender than those with a temperature of +20°F. However, there seemed to be no particular difference between the steaks frozen to -10° and -40°F.

In a later study, Hiner and Hankins (1947), cut one and one-half-inch cubes from short loins that had aged five days. Samples were frozen at +18°, 0°, -10°, -40° and -114°F. for 24 to 36 hours. Another set was frozen at 0°F. after 5, 10, 15, 25 and 35 days of aging. Again, they found that tenderness increased with freezing, but the effect decreased with longer holding periods. Freezing at +18°F. withdrew the water from the muscle fibers which was not reabsorbed on thawing. Thus, a relatively large amount was lost in drip from the meat. At the lower temperatures, water was frozen within the fiber thus splitting it, and, in this case, the water seemed to be reabsorbed in larger quantities.

Recent work by Paul and Bratzler (1955) supported the findings of Hankins and Hiner (1940). After three days of aging on the carcass, some of the steaks from eight pair of longissimus dorsi muscles of U. S. Prime, Good and Commercial grades, were frozen at -18°C. and others were held at 5° to 7°C. for the same length of time. After one day of frozen storage they were thawed in several ways and cooked in deep fat to 63°C. Both additional cold storage and freezing after three days of aging increased tenderness. Within the time studied (0, 1 and 2 days additional storage) cold storage was nearly as effective as freezing and thawing in increasing tenderness. Frozen steaks cooked without thawing were less tender than those thawed before cooking.

Other workers have thrown some doubt on the tenderizing effect of freezing and frozen storage, however. Seven years of frozen storage at -30° and -10°F. had little effect on the appearance and tenderness of beef steaks tested by Ramsbottom (1950). The shear values of pork loin roasts stored up to 72 weeks at 10°, 0°, -10° and -20°F. by Hall et al. (1949) indicated that longtime storage at any of the storage temperatures studied resulted in an increased resistance to shearing, i.e., a decrease in tenderness. Pearson and Miller (1950) concluded that freezer storage periods up to 180 days resulted in decreased tenderness of longissimus dorsi steaks regardless of the rate of freezing, and in a measurable deterioration of quality.

Amount and Distribution of Connective Tissue. Differences in tenderness between individual muscles and between positions in a muscle have been found by several investigators, and in some cases these differences seem to be related to the amount of connective tissue present. It was demonstrated by Hiner et al. (1955) that muscles which received a great deal of use, such as the less tender semimembranosus, semitendinosus, and biceps femoris, had more and larger elastic and collagenous fibers than those that were not used as much, such as the more tender gluteus medius and psoas major. If fatty deposits were present, the collagenous tissue formed a loose network, but if fat was absent, the collagenous fibers bunched together.

Twenty-five major muscles from each of three U. S. Good grade heifer carcasses were tested organoleptically and by the Warner-Bratzler shearing apparatus for relative tenderness on both raw and cooked meat (Ramsbottom et al., 1945). It was reported that the presence of large, well-defined fasciculi with a great deal of perimysia, such as was found in the superficial pectoral, gave a coarse, tough texture. The smooth, fine texture of the psoas major did not have enough connective tissue to divide the muscle into distinct bundles, and so was very tender. It was interesting to note, however, that a better correlation was obtained between the amount of connective tissue and raw shear readings than between the amount of connective tissue and cooked shear readings. In the order of increasing shear values for raw meat, some of the muscles listed were: longissimus dorsi, psoas major, adductor, vastus lateralus, semimembranosus, rectus femoris and semitendinosus.

Later work by Strandine et al. (1949) reported histological studies on 50 of the principal beef muscles. A variation in size and arrangement of the fasciculi and the connective tissue was noted when the muscles were cut transversely. Both elastic and collagenous fibers varied from muscle to muscle in respect to size and quantity. The correlation coefficient for the histological and organoleptic tenderness ratings was 0.7 which showed that connective tissue is a significant factor influencing tenderness, but not the only one.

Harrison et al. (1949) also reported that the smaller the amount of connective tissue in muscles, the more tender the beef. They listed several muscles in order of decreasing tenderness of the cooked meat: psoas major, longissimus dorsi (rib section), semitendinosus, semimembranosus and longissimus dorsi (loin section).

The Effect of Cooking on the Palatability of Beef

Effect on Color. According to Lowe (1955), when beef reaches an internal temperature of 50°C. the color changes gradually from a deep red or pink to a lighter tint and, with higher temperatures, eventually turns to a brownish color. This change is brought about by the denaturation of the pigment myoglobin to metmyoglobin.

Effect on Flavor and Aroma. Crocker (1948) stated that the flavor of raw meat is mostly in the juice and is rather weak, sweet, salty, and blood-like. He explained that the "meaty flavor" of cooked meat is caused by the breakdown of the amino acids of protein, particularly those in the fiber. These breakdown products consist of ammonia, amines, hydrogen sulfide and low aliphatic acids. The flavor of meat is primarily an odor that is a combination of small quantities of several products that results in a pleasant and fragrant odor.

When cuts from three muscles from the round of eight grass-fed animals of low grade (4 U. S. Commercial, 2 High Commercial and 2 Good) were cooked by dry heat to 160°F. (71°C.) and 176°F. (80°C.) by Hood et al. (1955), they were scored significantly higher in aroma and flavor than the same cuts cooked by braising. The meat cooked by dry heat to 176°F. was rated slightly higher for both flavor and aroma than that cooked by dry heat to 160°F. It was interesting to note that meat from animals grazed in the summer was scored significantly higher in flavor than meat from those grazed in the winter.

Paul et al. (1956) compared the flavor of steaks from several muscles in the round of six U. S. Commercial grade cows cooked by dry and by moist heat (braised). Similar to the work done by Hood et al. (1955) they found that those cooked by dry heat were considered superior to the braised steaks. The semimembranosus and adductor muscles received the highest flavor scores and the biceps femoris the lowest scores.

Harrison et al. (1953) found no significant differences in the flavor of loin steaks, U. S. Commercial grade, cooked by dry heat to a medium- (158°F. or 70°C.) or well-done (176°F. or 80°C.) stage. This result is not in agreement with that obtained by Hood et al. (1955). However, Harrison et al. (1953) did find a significant difference in flavor scores for two groups of rib roasts that were cooked to 158°F. (70°C.) and 176°F. (80°C.); those cooked to the lower temperature were scored higher.

Effect on Juiciness. Siemers and Hanning (1953) studied the effect of suet on the juiciness of meat cooked at several temperatures and for various times. They used small rectangular pieces of semimembranosus covered with a layer of suet and small quantities of ground meat mixed with suet in a Waring Blendor. Proportions of lean to suet were 100, 75 and 50 percent. Cooking temperatures were 70°, 80°, 90° and 98°C. and cooking times were 5, 10, 20 and 30 minutes. Increased temperature and time of cooking increased juice losses significantly. The loss of the water phase of the juice was decreased by increasing the amount of suet. This was true both when the suet was mixed with the meat and when it was used as a covering for the meat. Although longer cooking and increased loss of juice lowered judges' scores considerably, the judges could not detect the lower loss of juice in the suet covered sample. The relative vapor pressure was used to measure the amount of bound water in the meat. This study showed that more water was bound as the cooking period was extended.

Satorius and Child (1938a) roasted semitendinosus muscles to internal temperatures of 58°, 67° and 75°C. and found that the total cooking losses increased and press fluid yields decreased between 67° and 75°C., but no change was noted between 58° and 67°C.

According to Noble et al. (1934), rib roasts cooked to 61°C. yielded more juice when subjected to 3800 pounds pressure per square inch than those cooked to 75°C. Rounds were juicier than ribs when cooked to both 61° and 75°C. Cover and Smith (1956) found that steaks from the loin and bottom round were more juicy when broiled than when braised.

The finding of the two previously mentioned workers agreed with work done by Paul et al. (1956) in which muscles from the round of U. S. Commercial grade cows cooked by dry heat to an internal temperature of 71°C. were juicier than those braised to an internal temperature of 80°C. The biceps femoris muscle was the juiciest and the semitendinosus the least juicy. The muscles studied were the semimembranosus, semitendinosus, adductor and biceps femoris. The steaks from beef-type animals were slightly more juicy than those from the dairy-type. The correlation coefficient for the relationship between juiciness scores and the losses during cooking for all animals was -0.497 ($P<0.01$) for the steaks cooked by dry heat and -0.568 ($P<0.01$) for the braised steaks. Thus, the juiciness scores were lowered as the losses increased. Rib roasts and loin steaks of U. S. Commercial grade steers cooked by dry heat by Harrison et al. (1953) to 158°F. (70°C.) were significantly more juicy than those cooked to 176°F. (80°C.).

Effect on Tenderness. Twenty-five major muscles from each of three U. S. Good grade heifers were rated by Ramsbottom et al. (1945) for relative tenderness by means of the Warner-Bratzler shearing apparatus and organoleptic scores. Since the pieces were small, they were cooked in lard maintained at 121.1°C. (250°F.) to an internal temperature of 76.7°C. (170°F.). The cooking time varied from 12 to 20 minutes depending on the weight and thickness of the cut, and the internal temperatures usually rose one or two degrees after removal from the lard. Some muscles increased in tenderness with cooking and others decreased, as was evident from the raw and cooked shear values. The meat cooked rapidly in lard and may have been less tender than oven-cooked meat would have been.

According to Ramsbottom et al. (1945) collagenous tissue changed considerably on cooking, but elastic tissue changed less. A sample of collagen (tendon) one-half inch in diameter had a raw shear value of 120 pounds, whereas the cooked value was 21.5 pounds. The raw shear value for a piece of elastic tissue (ligament) similar in size was 81.1 pounds, and the cooked shear value was 42.3 pounds. The short cooking periods used in this study shrank the muscle and started hydrolyzation of the collagenous tissue. The muscle fibers of cooked meat were more compact than those in raw meat and the collagenous fibers were enlarged and irregular in shape.

The effect of slow and rapid heat penetration on the tenderness of beef cooked at several intervals after slaughter was studied by Paul et al. (1948). The semitendinosus and biceps femoris muscles from three animals were used, and three paired steaks and three paired roasts were cut from each muscle. The steaks were fried in deep fat at 150°C. to an internal temperature of 63°C. and the roasts were oven-cooked at 163°C. to the same internal temperature after 1 to 1½, 6, 13, 25, 49 to 54 and 145 to 150 hours post mortem. The shear values for the steaks increased up to 13 hours after slaughter, and then decreased. Shear values were highest for the roasts cooked after 1 to 1½ hours post mortem. Paul et al. (1948) theorized that the cuts had not yet gone into rigor at 1 to 1½ hours, and that the heat penetration of the steaks was quick enough to inactivate the enzymes present before rigor set in. The heat penetration of the roasts, however, was slow enough that rigor set in before they reached the desired internal temperature.

The effect of metal skewers on the cooking time and tenderness of beef was studied by Cover (1941). She cooked paired beef round, arm-bone and standing rib roasts to an internal temperature of 80°C. in a 125°C. (257°F.) oven. Six-inch nickel-plated copper skewers were used in one roast of each pair. The paired-eating method was used to compare tenderness of the semimembranosus, triceps brachii and the longissimus dorsi muscles. The skewers decreased the cooking time, cooking losses and tenderness of the meat; whereas long, slow cooking of the unskewered meat increased the tenderness. Cover (1941) concluded that differences in cooking time affect tenderness of meat more than the temperature at which it is cooked.

In later work, Cover (1943) compared the effect of extremely slow rates of heat penetration on the tenderness of beef rib, arm-bone and bottom round roasts. The cuts were cooked rare and well-done at oven temperatures of 80°C. (176°F.) and 125°C. (257°F.), and tested for tenderness by the paired-eating method and the Warner-Bratzler shearing machine. When the rate of heat penetration was slow enough to require 30 hours or more for the meat to lose its pink color, the roasts were always tender. If less time was used, the roasts were not always tender. In the 80°C. oven, the well-done roasts were not plump even though the internal temperature had reached 70°C., which was high enough for the heat to have contracted any collagen present. Cover concluded that the conversion of collagen to gelatin had advanced beyond the point where contraction could take place. In the well-done bottom rounds cooked at 80°C., the large amount of connective tissue seemed to be completely changed from its hard, tough state to a moist, viscous mass. Since the moisture loss was quite moderate in amount and the coagulation time was so long, the water of hydration was released slowly enough so that it could be used effectively to convert collagen to gelatin.

Four muscles from the round were cooked by Hood et al. (1955) by braising and by roasting to internal temperatures of 160°F. (71°C.) and 176°F. (80°C.). Except for a significant difference between thick and thin cuts, there was little variation in shear values and tenderness scores for the meat given the various treatments. The thinner cuts were scored less tender and had higher shear values than the thick ones. Samples cooked by dry heat were scored slightly more tender than those cooked by moist heat, but the difference was not significant. The overall mean shear value for the raw meat was 26.32 pounds, and 17.25 pounds for the cooked meat. For the meat used in this study, the internal temperature of 176°F. was too high for what was considered to be the optimum degree of doneness. Even steaks cooked to 160°F. were considered overcooked.

In unpublished work done by Harrison et al. (1953) U. S. Commercial grade rib roasts and loin steaks cooked to 158°F. (70°C.) were scored significantly more tender than those cooked to 176°F. (80°C.). Generally, the correlation coefficients for the tenderness scores and shear values of these cuts were not significant.

When the semitendinosus muscle was cooked to three internal temperatures (58°, 67° and 75°C.) by Satorius and Child (1938), the diameter of the muscle fibers decreased and tenderness increased up to 67°C. Between 67° and 75°C. the muscle fiber diameter did not change, but tenderness decreased.

EXPERIMENTAL PROCEDURE

Meat Used

U. S. Good grade long hindquarters (the round, tenderloin and loin cut off from the chuck between the fourth and fifth rib) from three steers were purchased from a Kansas City packing house and shipped to the animal husbandry meats laboratory at Kansas State College six to eight days after slaughter. Two or three days later, the muscles and their respectively coded roasts, as presented in Table 1, were dissected from the long hindquarters.

As the muscles were dissected, trimmed of most of the visible fat and cut into roasts, samples were removed for histological and chemical studies on the raw meat. Plates I through VIII present photographs of muscles similar to those samples in this study. The samples for histological studies were preserved

Table 1. The muscles used and their respectively coded roasts.

Muscle	Roast code
Psoas major	A, B
Adductor	C, D
Rectus femoris	E, F
Vastus lateralus	G, H
Semitendinosus	J, K, L
Longissimus dorsi (loin)	M, N, O
Semimembranosus (posterior)	P, Q
Semimembranosus (anterior)	R, S
Longissimus dorsi (rib)	T, U, V

in a physiological salt solution and formalin. Samples for the chemical analyses were ground and frozen. The histological studies and the chemical analyses are part of a larger study and the data from this work are not included in this thesis. The individual roasts were wrapped in 0.0015 gauge aluminum foil and labeled with the animal number, roast code and l or r for left and right side of the animal, respectively. The meat was immediately frozen at -20°F. on plates, containing coils, in a household, upright freezer and held there prior to defrosting and cooking. All roasts were cooked within eight weeks after freezing.

Statistical Design

Three internal temperatures (55°, 70° and 85°C.) that represent rare, medium- and well-done beef were used to determine the end-point of cooking.

EXPLANATION OF PLATE I

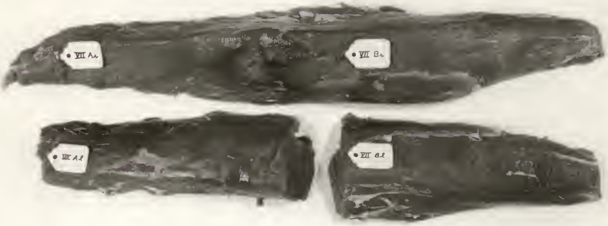
Top of plate:

Psoas major muscle, right side from Animal VII.

Bottom of plate:

Psoas major muscle from left side of Animal VII, divided into roasts A1 (anterior end) and B1 (posterior end).

PLATE I



EXPLANATION OF PLATE II

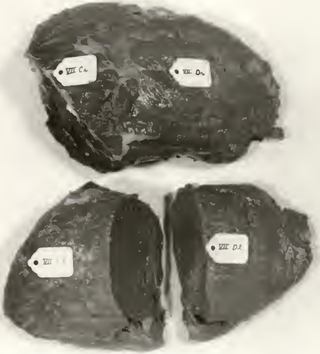
Top of plate:

Adductor muscle, right side from Animal VII.

Bottom of plate:

Adductor muscle from left side of Animal VII, divided into roasts C1 (proximal end) and D1 (distal end).

PLATE II



EXPLANATION OF PLATE III

Top of plate:

Rectus femoris muscle, right side from Animal VII.

Bottom of plate:

Rectus femoris muscle from left side of Animal VII, divided into roasts E1 (proximal end) and F1 (distal end).

PLATE III

EXPLANATION OF PLATE IV

Top of plate:

Vastus lateralus muscle, right side from Animal V.

Bottom of plate:

Vastus lateralus muscle from left side of Animal V, divided into roasts G1 (proximal end) and H1 (distal end).

PLATE IV

EXPLANATION OF PLATE V

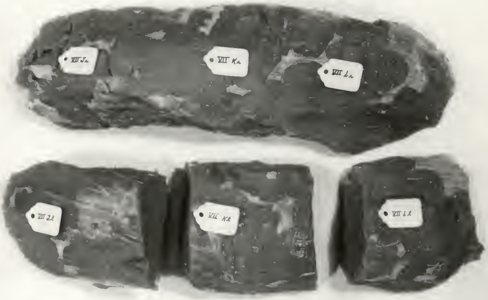
Top of plate:

Semitendinosus muscle, right side from Animal VII.

Bottom of plate:

Semitendinosus muscle from left side of Animal VII, divided into roasts J1 (proximal end), L1 (distal end) and K1 (center).

PLATE V



EXPLANATION OF PLATE VI

Top of plate:

Loin section of the longissimus dorsi muscle, right side from Animal VII.

Bottom of plate:

Loin section of the longissimus dorsi muscle from left side of Animal VII, divided into roasts M1 (anterior end), O1 (posterior end) and N1 (center). The slices between the roasts removed for chemical analyses also are shown.

PLATE VI

EXPLANATION OF PLATE VII

Left side of plate:

Semimembranosus muscle, left side from Animal VI.

Right side of plate:

Semimembranosus muscle from right side of Animal VI divided into roasts Pr (posterior side, proximal end), Qr (posterior side, distal end), Rr (anterior side, proximal end) and Sr (anterior side, distal end). The slices between the roasts removed for chemical analyses also are shown.

PLATE VII

EXPLANATION OF PLATE VIII

Top of plate:

Rib section of the longissimus dorsi muscle, left side from Animal VI.

Bottom of plate:

Rib section of the longissimus dorsi muscle from right side of Animal VI, divided into roasts Tr (anterior end), Vr (posterior end) and Ur (center). The slices between the roasts removed for chemical analyses also are shown.

PLATE VIII

For three of the muscles, an incomplete block design which consisted of the left and right sides of each muscle, was used to determine the internal temperatures, in degrees centigrade, of the roasts as listed in Table 2. A muscle from one animal was one replication. The longissimus dorsi muscle was divided into the anterior and posterior parts and treated as two muscles.

Table 2. Internal temperatures at the end of the cooking period for roasts from three muscles.

Muscle	Animal number	Roasts and internal temperatures, °C.					
Semitendinosus		Jl	Jr	Kl	Kr	Ll	Lr
	II	70	55	85	55	70	85
	IV	85	70	55	85	70	55
	V	55	70	85	70	55	85
Longissimus dorsi (loin section)		Ml	Mr	Nl	Nr	Ol	Or
	II	85	55	70	55	85	70
	IV	70	85	55	85	55	70
	V	85	55	55	70	70	85
Longissimus dorsi (rib section)		Tl	Tr	Ul	Ur	Vl	Vr
	II	55	70	85	55	70	85
	IV	85	55	70	85	70	55
	V	85	55	55	70	85	70

J - proximal end roasts from the respective muscle.
M, T - anterior end roasts from the respective muscles.
L - distal end roasts from the respective muscles.
O, V - posterior end roasts from the respective muscles.
K, N, U - middle roasts from the respective muscles.
l - left side of animal.
r - right side of animal.

A randomized complete block design was used to determine the internal temperature of roasts from six of the muscles. The specific design is given in Table 3. The semimembranosus muscle was divided into the posterior and anterior parts, and treated as two muscles.

Table 3. Internal temperatures at the end of the cooking period for roasts from six muscles.

Muscle	Animal number	Roasts and internal temperatures, °C.			
Psoas major		Al	Ar	Bl	Br
	II	55	70	55	70
	IV	70	55	70	55
	V	70	55	70	55
Adductor		Cl	Cr	Dl	Dr
	II	70	85	85	70
	IV	85	70	85	70
	V	70	85	70	85
Rectus femoris		El	Er	Fl	Fr
	II	85	70	85	70
	IV	70	85	85	70
	V	85	70	85	70
Vastus lateralus		Gl	Gr	Hl	Hr
	II	85	70	70	85
	IV	85	70	70	85
	V	70	85	85	70
Semimembranosus (posterior)		Pl	Pr	Ql	Qr
	II	85	70	85	70
	IV	70	85	70	85
	V	70	85	70	85
Semimembranosus (anterior)		Rl	Rr	Sl	Sr
	II	70	85	70	85
	IV	85	70	85	70
	V	85	70	85	70

A - anterior end roast from the respective muscle.
B - posterior end roast from the respective muscle.
C, E, G, P, R - proximal end roasts from the muscles.
D, F, H, Q, S - distal end roasts from the muscles.
l - left side of animal.
r - right side of animal.

Cooking Methods and Data Obtained

Before each cooking period, roasts from one paired muscle were defrosted approximately 48 hours in a refrigerator maintained at 40° to 45°F. Two or three roasts were cooked at the same time in household electric deep fat fryers. One fryer was used for each roast. In preliminary work, it was determined that a cooking temperature of 110°F. for the fat gave satisfactory results. Therefore, the hydrogenated vegetable fat used for cooking[1] was heated to 120° to 127°C., the meat was added, the temperature of the fat was allowed to drop to 110°C., and it was maintained at that temperature during cooking.

The time required for every five degree rise in the internal temperature of the meat was recorded throughout the cooking period. Internal temperatures of 55°, 70° and 85°C. (rare, medium- and well-done, respectively) were used for determining the end-point of cooking. After removal from the fat and before the roasts were weighed, they were allowed to drain on a wire rack for ten minutes. During that time the maximum internal temperature was noted.

Total cooking losses were calculated, in percent, from the weight of the thawed meat and the weight of the cooked meat. One-inch cores, parallel to the fiber axis, were removed from the cooked roasts and were tested for tenderness on the Warner-Bratzler shearing apparatus. This apparatus indicated the number

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[1]Primex

of pounds of force necessary for a dull blade to cut through a core of meat one-inch in diameter. Each core was cut approximately five times and the readings averaged.

Samples for press fluid yields were obtained by grinding meat from each roast in a Universal No. 3 food grinder. Twenty-five grams of ground meat were packed between four layers of filter paper in a circle of cheese cloth two layers thick within a 2.25-inch metal cylinder. A leather disc and a heavy plunger were placed on the meat in the cylinder and set in a shallow stainless steel pan. The whole assembly was then placed in the hydraulic Carver Laboratory Press, and pressure was gradually applied according to the following schedule:

Time in minutes	Pressure in pounds[1]
1.0	5,000
2.0	7,500
3.0	10,000
5.0	10,000
7.5	12,500
10.0	15,000
11.0	16,000
15.0	16,000

After the pressure was released, any juice or fat still clinging to the bottom of the cylinder was scraped into the pan with a rubber policeman. The fluid in the pan was carefully poured and scraped into a centrifuge tube that was graduated to 0.1 milliliter. Duplicate determinations were made on each sample. The tubes were allowed to stand overnight in the refrigerator. The

[1]The pressure in the schedule refers to the load on the 1.25-inch ram of the test cylinder. The maximum load on the meat was 4,000 pounds per square inch.

next day the volume of the total press fluid, fat and serum were recorded.

A panel of 10 judges scored the meat for aroma, flavor, tenderness and juiciness. The range of scores used was from 1, extremely poor, to 10, extremely good. Tenderness scores were based on the number of chews required to completely masticate a bite of a certain size. The thickness of the samples was regulated by the use of a General home slicer. Each judge received a slice from approximately the same place in the roast every time. The scores for each factor were averaged.

Preferences for juiciness and tenderness also were given by the panel. After the samples were rated according to preference, the sample that was rated first was assigned a score of one, the sample that was rated second a score of two, etc. When several samples were rated the same, the sum of the scores they represented was divided equally among them. These scores that were assigned to the judges' ratings were then averaged; thus, the lower the score, the higher the preference rating.

Statistical Analyses

Analyses of variance were run to study the effect of the degree of cooking on cooking losses, cooking time, shear values, press fluid yields and palatability factors. When significant differences occurred among three treatments, i.e., three internal temperatures, two-way tables of means were analyzed by least significant differences.

In addition, correlation coefficients were determined from data on roasts from each muscle cooked to each internal temperature for tenderness scores and shear values, juiciness scores and press fluid yields, cooking losses and juiciness scores and cooking losses and press fluid yields.

RESULTS AND DISCUSSION

Objective Tests

Heat Penetration. The coagulation of proteins involves an endothermic process, that is, during coagulation, heat is absorbed, and a lag occurs in the rate at which the internal temperature of meat rises. Thus, the plateaus or flattened areas in heat penetration curves are an indication of intracellular protein coagulation.

The heat penetration curves for this study are presented in Figs. 1 through 9. Generally, the steepness of the heat penetration curves tended to lessen at 55° to 60°C. This is as might be expected from Lowe's (1955) statement that coagulation of the muscle protein probably begins at 60°C. or below. No particular difference was noted in the heat penetration curves between roasts from the right and left sides of the carcasses. However, the roasts from the proximal end of the muscles had slower rates of heat penetration than those from the distal end. No consistent difference in the rate of heat penetration was evident between the anterior and posterior roasts.

The smallest roasts, which averaged about 1.0 pound and were from the long, slender psoas major muscle, cooked quickly and had short and fairly straight heat penetration curves; whereas the

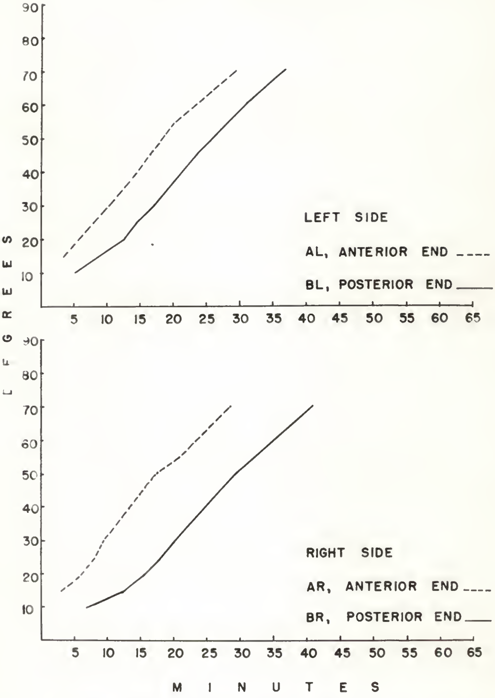

Fig. 1. Average heat penetration curves for the psoas major muscle. Top of figure, left muscle; bottom, right muscle.

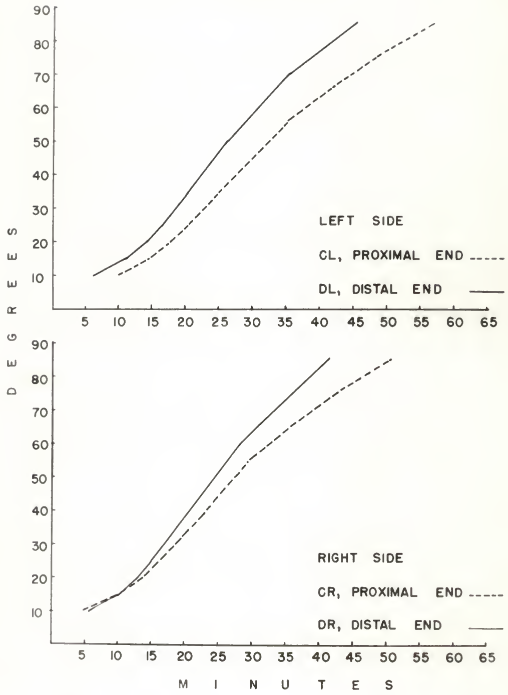

Fig. 2. Average heat penetration curves for the adductor muscle. Top of figure, left muscle; bottom, right muscle.

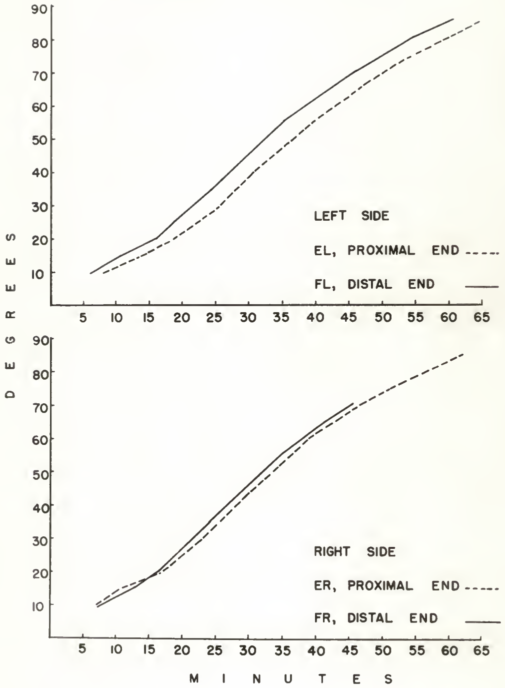

Fig. 3. Average heat penetration curves for the rectus femoris muscle. Top of figure, left muscle; bottom, right muscle.

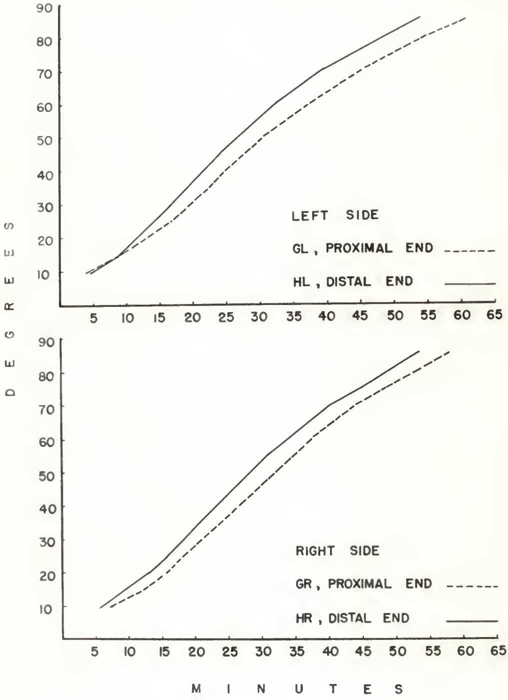

Fig. 4. Average heat penetration curves for the vastus lateralus muscle. Top of figure, left muscle; bottom, right muscle.

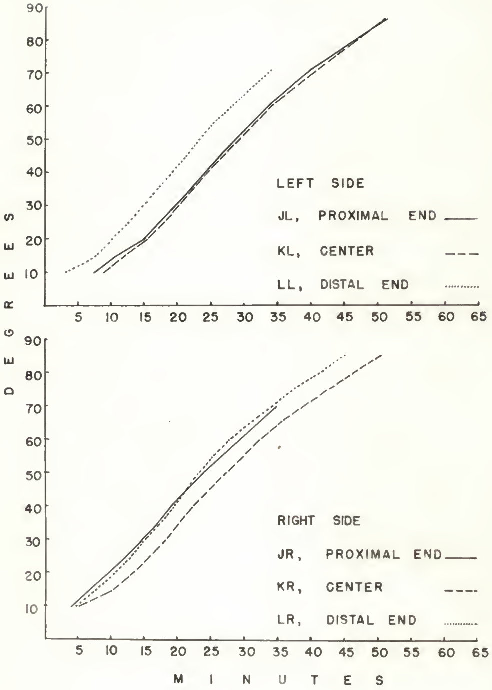

Fig. 5. Average heat penetration curves for the semitendinosus muscle. Top of figure, left muscle, bottom, right muscle.

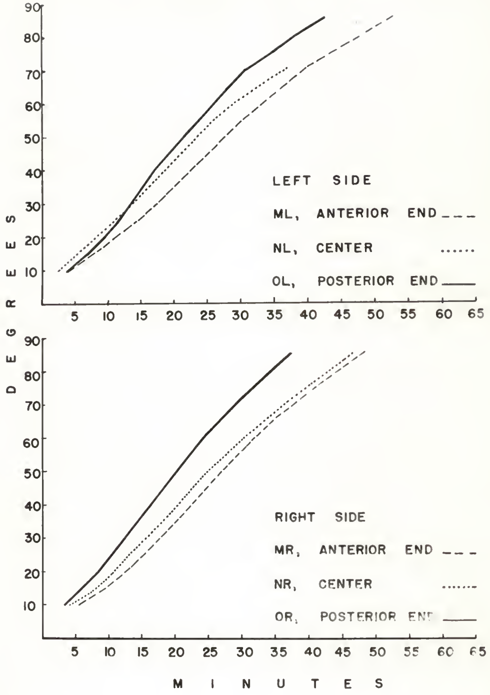

Fig. 6. Average heat penetration curves for the longissimus dorsi (loin) muscle. Top of figure, left muscle; bottom, right muscle.

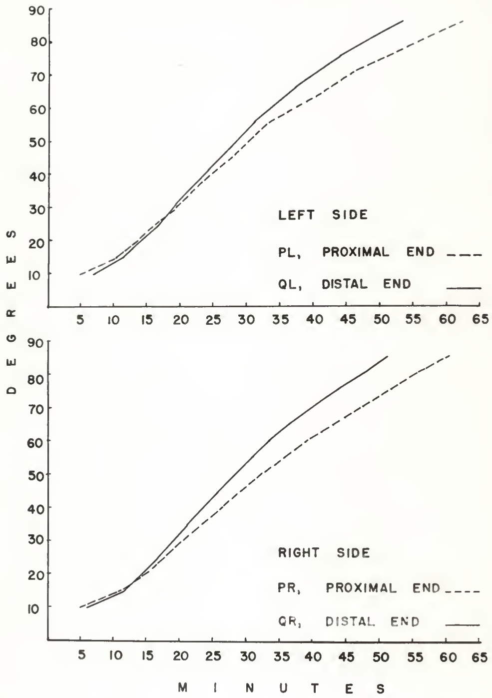

Fig. 7. Average heat penetration curves for the semimembranosus (posterior) muscle. Top of figure, left muscle; bottom, right muscle.

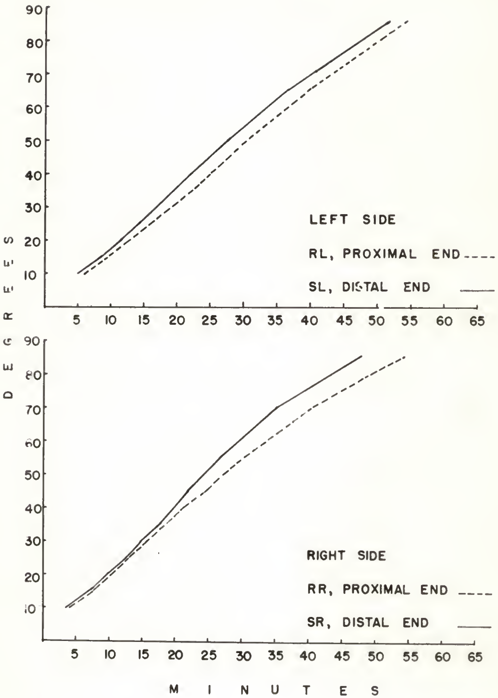

Fig. 8. Average heat penetration curves for the semimembranosus (anterior) muscle. Top of figure, left muscle; bottom, right muscle.

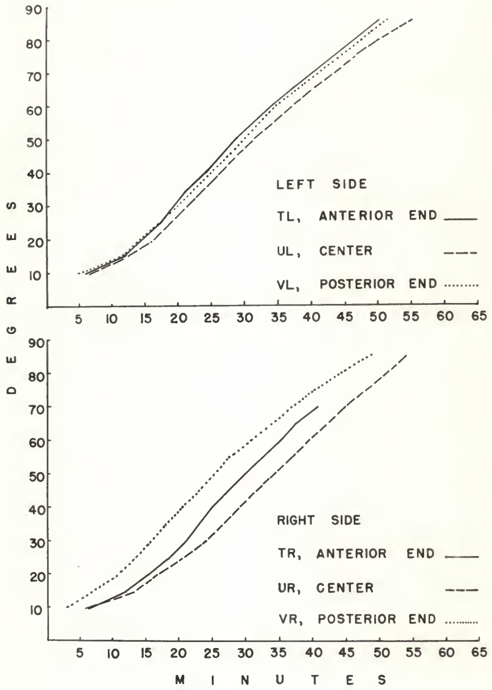

Fig. 9. Average heat penetration curves for the longissimus dorsi (rib) muscle. Top of figure, left muscle; bottom, right muscle.

largest, most blocky, compact cuts, which averaged about 1.7 pounds and were from the semimembranosus muscle, took longer to cook and so had longer, less steep heat penetration curves (Figs. 1 through 9 and Table 4). It was observed that the largest roasts were more "done" than the smallest roasts that were cooked to the same internal temperature. This same condition was noted by Jacobson and Fenton (1956) in preliminary work with the semimembranosus, longissimus dorsi, psoas major and adductor muscles from the beef carcass.

The roasts that were removed from the fat when they reached an internal temperature of 55°C. usually rose 10 to 13 degrees, unless the roast was exceptionally flat as were some of the longissimus dorsi roasts, in which case the temperature rose only a few degrees, if at all. The internal temperature of roasts cooked to 70°C. often rose five to six degrees and those cooked to 85°C. rose only one or two degrees after removal from the fat, if at all. When Ramsbottom et al. (1945) cooked roasts from 25 beef muscles in deep fat, 121.1°C., to an internal temperature of 76.7°C., the internal temperature usually rose one or two degrees after removal from the fat.

Cooking Time and Cooking Losses. The average of mean cooking time, in minutes per pound, ranged from about 22 to 30 for the meat cooked to 55°C., from 27 to 38 for that cooked to 70°C., and from 35 to 48 for that cooked to 85°C. (Table 4). Significant to very highly significant increases in cooking time resulted from increased internal temperatures. Total cooking times for roasts from all muscles ranged from approximately 25 to 65 minutes.

Table 4. Average of mean weight, cooking time, total cooking losses, press fluid yields and shear force values.

Muscle	Int. temp. °C.	Wt. lbs.	Ckg. time min/lb.	Ckg. losses %	Shear force lbs.	Press fluid ml./25 g.
Psoas major	55	1.3	22.8	22.1	11.9	7.6
	70	1.2	28.6*	27.5*	13.3	7.3
Adductor	70	1.0	38.3	33.7	28.4	6.7
	85	1.1	46.2*	37.7*	26.5	6.3
Rectus femoris	70	1.5	33.3	34.1	23.5	6.7
	85	1.6	42.3*	37.6*	26.3	6.2
Vastus lateralus	70	1.4	30.6	34.3	24.6	6.8
	85	1.7	41.0*	37.7	21.6	5.6*
Semitendinosus	55	1.1	30.2	26.9	21.7	8.3
	70	1.1	38.3*	29.8*	21.7	7.8 near *
	85	1.1	48.3*	35.0*	20.7	6.9*
			lsd=3.5	lsd=1.4		lsd=0.6
Longissimus dorsi (loin)	55	1.4	22.3	27.5	13.2	7.8
	70	1.4	26.9	31.9*	17.2	6.6*
	85	1.6	34.5*	34.7*	15.1	5.6 near*
			lsd=6.7	lsd=2.8		lsd=1.1-
Semimembranosus (posterior)	70	1.7	28.3	32.1	29.2	7.5
	85	1.7	36.1*	36.7*	25.4	6.3*
Semimembranosus (anterior)	70	1.7	27.2	33.3	27.6	7.3
	85	1.7	35.5*	37.7*	27.6	6.1*
Longissimus dorsi (rib)	55	1.3	26.2	28.6	16.8	7.4
	70	1.4	32.7*	32.1*	15.8	6.5*
	85	1.4	40.7*	35.8*	15.4	6.0 near*
			lsd=3.7+	lsd=1.4		lsd=0.5+

* - significant
lsd - least significant difference

The average of mean cooking losses and the significance of the effect of internal temperature on cooking losses are shown in Table 4. The average of mean percentage weight losses of the roasts always increased as the internal temperature was raised. Cooking losses for those roasts cooked to 55°C. ranged from 22.1 to 28.6 percent, those cooked to 70°C. from 27.5 to 34.3 percent and those cooked to 85°C. from 34.7 to 37.7 percent. With the exception of roasts from the vastus lateralus, the increases ranged from significant to very highly significant. These results are in agreement with those of Satorius and Child (1938a) who roasted beef to internal temperatures of 58°, 67° and 75°C.

Shear Values. Although shear force values and tenderness scores are both used to measure tenderness of meat, most workers agree that shearing force, i.e., the number of pounds pressure required for a blade to cut through a one-inch core of meat, does not measure the same quality of "tenderness" that a taste panel does.

The average of mean shear values for the roasts cooked in this study and the significance of the effect of internal temperature on shear force are given in Table 4. The three degrees of doneness to which the roasts were cooked had no significant effect on the shear values for any of the muscles. The shear values of roasts from the nine muscles were not all affected in the same way. Moreover, the results for each roast were not consistent as is shown in Table 10 (Appendix). Roasts from those muscles that were toughened by cooking to higher internal temperatures were from the psoas major and the rectus femoris. Roasts from those muscles that had less shearing resistance after each increase in internal temperature were from the adductor, vastus lateralus, the posterior part of the semimembranosus, and the longissimus dorsi (rib).

The anterior roasts of the semimembranosus did not change in tenderness between 70° and 85°C. Those from the longissimus dorsi (loin section) decreased in tenderness from 55° to 70°C. but increased slightly between 70° and 85°C. In contrast, when Satorius and Child (1938a) cooked the semitendinosus muscle to 58°, 67° and 75°C., the tenderness, as measured by shear force values, increased between 58° and 67°C., but decreased from 67° to 75°C.

Roasts from the psoas major muscle were the most tender, but those from both the loin and rib sections of the longissimus dorsi muscle were close to them in tenderness. Average of the mean shear values for the psoas major were 11.9 and 13.3 pounds for roasts cooked to 55° and 70°C., respectively; whereas, the shear values for the longissimus dorsi (loin) roasts were 13.2 and 17.2 pounds and those for the longissimus dorsi (rib) were 16.8 and 15.8 for the same temperatures. The highest shear values ranged from 24 to 29 pounds and were obtained from roasts from the semimembranosus, adductor and rectus femoris muscles. Regardless of these differences in shear values for roasts cooked to the three internal temperatures, they were not statistically significant. Ramsbottom et al. (1945) found that the shear force of the psoas major and longissimus dorsi muscles were 7.1 and 8.3, respectively when they were cooked in lard at 121.1°C. to an internal temperature of 76.7°C., and these were the most tender of the 25 muscles tested.

<u>Press Fluid Yields</u>. Press fluid yields, or the juices expressed from meat under pressure, are sometimes considered to be an indication of the relative juiciness of meat. However, such workers as Gaddis et al. (1950) and Satorius and Child (1938b) have shown that the amount of press fluid was not significantly related to juiciness scores given by a taste panel. In addition, it would seem logical to assume that meat having high cooking losses would have low press fluid yields, but this is not always the case. When the semitendinosus beef muscle was heated to 58°C. internal temperature by Child and Satorius (1938) at oven temperatures of 125°, 150°, 175° and 200°C., there was no difference in press fluid yields but cooking losses increased with increased oven temperatures.

The average press fluid yields for the study reported here, which always showed a decrease with each increase in internal temperature, are presented in Table 4. The differences in press fluid yields attributable to increased internal temperatures were significant for roasts from the vastus lateralus, semimembranosus (anterior), semimembranosus (posterior), semitendinosus, longissimus dorsi (loin) and longissimus dorsi (rib), Table 4. The differences in press fluid yields for roasts from the rectus femoris, adductor and psoas major were non-significant. Since the roasts cooked to the higher internal temperatures usually required a longer cooking time, the lower press fluid yields might be explained, at least in part, by the binding of water to the protein molecule. Data to support this idea were given by Siemers and Hanning (1953), who found that more water was bound as the cooking period was extended. The results also agree with work done by Harrison et al. (1953) who reported that rib roasts and club and Porterhouse steaks cooked to 70°C. were significantly ($P < .002$) more juicy than those cooked to 80°C. as evidenced by both press fluid yields and juiciness scores.

In the study reported here, the semitendinosus roasts yielded the greatest amount of press fluid at all three degrees of doneness. In contrast, when the semimembranosus, semitendinosus, adductor and biceps femoris muscles were tested by Paul et al. (1956), the semitendinosus was the least juicy.

Correlation coefficients for cooking losses and press fluid yields are presented in Table 5. There were no significant correlation coefficients for these two factors for meat that was cooked to 55°C. There seemed to be a closer relationship between cooking losses and press fluid yields of the meat cooked to 85°C. than of that cooked to 70°C. A highly significant relationship existed between cooking losses and press fluid yields for roasts from the semimembranosus (anterior) cooked to 70°C. ($r = -.949$) and for those from the adductor ($r = -.865$), rectus femoris ($r = -.897$), longissimus dorsi, loin ($r = -.842$) and the longissimus dorsi, rib ($r = -.813$) cooked to 85°C.

Palatability Factors

Aroma and Flavor. There were no significant differences in aroma scores for the various roasts cooked, Table 6. Average of mean aroma scores indicate that there was a tendency for roasts cooked to higher internal temperatures to be scored the same as,

Table 5. Correlation coefficients for cooking losses and press fluid yields, cooking losses and juiciness scores, juiciness scores and press fluid yields and tenderness scores and shear values.

Factor	55°C.	70°C.	85°C.
Ckg, losses and press fluid			
Psoas major	-.780	-.469	
Adductor		-.614	-.865*
Rectus femoris		-.553	-.897*
Vastus lateralus		-.713	.265
Semimembranosus (posterior)		-.594	-.452
Semimembranosus (anterior)		-.949**	-.574
Semitendinosus	.739	-.120	-.579
Longissimus dorsi (loin)	-.767	.459	-.842*
Longissimus dorsi (rib)	-.187	-.375	-.813*
Ckg. losses and juiciness scores			
Psoas major	-.187	-.795	
Adductor		-.114	.578
Rectus femoris		-.717	-.732
Vastus lateralus		-.770	-.208
Semimembranosus (posterior)		.393	-.562
Semimembranosus (anterior)		-.340	.824*
Semitendinosus	.918**	-.265	-.625
Longissimus dorsi (loin)	-.153	-.195	-.610
Longissimus dorsi (rib)	.132	-.735	.236
Press fluid and juiciness scores			
Psoas major	-.199	.794	
Adductor		.510	.329
Rectus femoris		.163	.704
Vastus lateralus		.137	.781
Semimembranosus (posterior)		-.740	.091
Semimembranosus (anterior)		.376	-.666
Semitendinosus	.708	.699	.849*
Longissimus dorsi (loin)	-.208	-.439	.330
Longissimus dorsi (rib)	-.919**	.033	-.126
Shear values and tenderness scores			
Psoas major	-.471	-.392	
Adductor		-.481	-.185
Rectus femoris		-.153	-.892*
Vastus lateralus		-.628	.088
Semimembranosus (posterior)		-.386	-.455
Semimembranosus (anterior)		-.701	-.816*
Semitendinosus	.217	-.068	.121
Longissimus dorsi (loin)	-.269	-.908*	-.480
Longissimus dorsi (rib)	-.296	-.262	-.463

* - significant
** - highly significant

Table 6. Average of the mean palatability scores for flavor, aroma, tenderness and juiciness. Maximum possible score, 10.

Muscle	Int. temp.	Aroma	Flavor	Tenderness	Juiciness
Psoas major	55	8.6	8.4	9.2	7.9
	70	8.7	8.4	9.2	7.6
Adductor	70	8.4	7.9	7.9	5.8
	85	8.4	7.6	7.9	5.3*
Rectus femoris	70	8.6	7.9	8.2	6.6
	85	8.7	8.0	8.3	6.3
Vastus lateralus	70	8.4	7.9	8.1	6.6
	85	8.4	7.6	8.2	5.6*
Semitendinosus	55	8.4	8.1	8.3	7.8
	70	8.4	8.2	8.4	6.9*
	85	8.6	8.1	8.4	6.3*
					lsd=0.5+
Longissimus dorsi (loin)	55	8.4	8.4	8.7	7.9
	70	8.6	8.2 *	8.4	6.8*
	85	8.7	8.1	8.7	6.0 near*
			lsd=0.3		lsd=0.9+
Semimembranosus (posterior)	70	8.6	8.1	8.2	6.6
	85	8.7	8.2	8.4	6.1
Semimembranosus (anterior)	70	8.7	8.0	7.9	6.0
	85	8.8	8.0	8.3*	5.5
Longissimus dorsi (rib)	55	8.5	8.3	8.4	7.4
	70	8.5	8.2	8.7	6.7
	85	8.6	8.3	8.7	6.4

* - significant
lsd - least significant difference

or slightly higher than those cooked to the lower internal temperature. Meat cooked by Hood et al. (1955) to 80°C. was rated slightly higher for both aroma and flavor than that cooked to 71°C.

There seemed to be no consistent trend, and there were no significant differences in flavor scores for the roasts in this study that could be attributed to internal temperatures, except in the case of roasts from the longissimus dorsi (loin), Table 6. Although statistically there were significant differences between the flavor scores for the longissimus dorsi (loin) that was cooked to 55°C. and that cooked to 85°C., the difference in the average of mean scores for the roasts cooked to these temperatures was only 0.3 of a point, and is not large enough to be of practical importance.

Tenderness Scores. Two opposing factors operate to affect changes in the tenderness of meat during cooking. The coagulation of muscle fiber protein tends to harden and toughen the meat, whereas the heating and partial hydrolysis of the collagenous tissue tends to tenderize the meat. It is logical to assume that a cut of meat containing a large amount of connective tissue would be more tender after a long cooking period than after a short cooking period. On the other hand, one containing relatively little connective tissue would be toughened by long cooking.

Although there were some exceptions, in this study, increases in internal temperature of the meat had a tendency to increase tenderness scores and scores for preferences ratings for tenderness, Tables 6 and 7. In roasts from only one muscle, the semimembranosus (anterior), were the differences attributable to internal temperature statistically significant, Table 6, and in this case the difference between the average of the mean scores was only 0.4 of a point on a 10 point scale.

The tenderness scores and the shear values did not always show similar trends, Tables 4 and 6. For example, according to the average of mean shear readings, roasts from the anterior part of the semimembranosus did not change in tenderness between 70° and 85°C., but the average of mean tenderness scores indicated that they increased in tenderness from a score of 7.9 to 8.3. For the rectus femoris muscle, the average of mean shear readings for these roasts showed a decrease in tenderness with an increase in internal temperature, whereas the tenderness scores indicated no real difference in tenderness. When U. S. Commercial grade rib roasts and loin steaks were cooked to 70° and 80°C. by Harrison et al. (1953), the meat cooked to the lower temperature was scored significantly more tender than that cooked to a higher temperature. Differences in tenderness scores for the steaks were significant at the one percent level, those for the roasts at the 0.2 percent level, and differences in the shear values for the roasts were significant at the five percent level.

Correlation coefficients for shear values and tenderness scores were run on the data for the roasts cooked to each internal temperature for each muscle. Out of the 21 coefficients calculated, only three were significant, Table 5. The correlation coefficients for these two factors were significant for roasts from the longissimus dorsi (loin) cooked to 70°C. ($r = -.908$) and for those from the semimembranosus, anterior ($r = -.816$) and the rectus femoris ($r = -.892$) cooked to 85°C.

Juiciness scores. The average of mean palatability scores for juiciness are given in Table 6, and the scores assigned to judges' preference ratings for juiciness are in Table 7. The higher the assigned preference score the lower the preference

Table 7. Scores[1] assigned to judges' preference ratings for juiciness and tenderness.

Muscle	Int. temp.	Juiciness	Tenderness
Psoas major	55	2.3	2.4
	70	2.7	2.6
Adductor	70	2.1	2.5
	85	2.9*	2.5
Rectus femoris	70	2.4	2.5
	85	2.6	2.5
Vastus lateralus	70	2.0	2.6
	85	3.0*	2.5
Semitendinosus	55	2.4	3.6
	70	3.7*	3.5
	85	4.4	3.5
		lsd=1.1	
Longissimus dorsi (loin)	55	2.3	3.2
	70	3.7*	3.9
	85	4.5 near*	3.4
		lsd=0.9+	
Semimembranosus (posterior)	70	2.3	2.7
	85	2.7	2.3
Semimembranosus (anterior)	70	2.3	2.8
	85	2.7	2.3
Longissimus dorsi (rib)	55	2.7	3.8
	70	3.7	3.3
	85	4.1	3.3

[1]Lower numbers indicate higher preference
* - significant
lsd - least significant difference

ratings. Each increase in the internal temperature of the meat resulted in a decrease in juiciness scores and an increase in assigned preference scores. The differences in juiciness scores that were attributable to internal temperature ranged from 0.6

to 1.1 points, and were significant for roasts from the adductor, vastus lateralus, semitendinosus, and longissimus dorsi (loin) muscles, Table 6. The differences in the scores assigned to judges' preference ratings that could be ascribed to internal temperature were significant for the roasts from these same muscles, Table 7.

As it was stated previously, press fluid yields as well as juiciness scores decreased and cooking losses increased as the internal temperature of the roasts increased. However, it was not always the same muscle that had the lowest juiciness scores and press fluid yields, and the highest cooking losses, Tables 4 and 6. For instance, roasts from the adductor received the lowest juiciness scores and had relatively high cooking losses, but these roasts did not yield the lowest amount of press fluid.

Correlation coefficients for the cooking losses and juiciness scores for roasts from each muscle cooked to 55°, 70° or 85°C. indicated that there was little, if any, relationship between these factors, Table 5. Since high cooking losses are usually associated with low juiciness scores, negative correlation coefficients would be expected. The majority of the correlation coefficients were negative, but none of them were statistically significant. Nevertheless, with an internal temperature of 70°C. four out of eight negative coefficients were relatively high. It should be pointed out that there were few data used to calculate the correlation coefficients. If there had been a larger number of degrees of freedom, no doubt these correlation coefficients would have been significant. Correlation coefficients for cooking losses and juiciness scores for the roasts from the semitendinosus cooked to 55°C. and those from the semimembranosus (anterior) cooked to 85°C. were positive and were statistically significant.

It is often assumed that high juiciness scores are associated with high press fluid yields. However, the correlation coefficients for juiciness scores and press fluid yields presented in Table 5 indicate that, in general, in this study these factors were unrelated. Only one positive correlation coefficient, that for the roasts from the semitendinosus muscle cooked to 85°C., was statistically significant; and only a few of the positive coefficients were relatively high. There were several negative coefficients, and one of these was significant. Again it should be stated that the few data involved in the calculation of the coefficients probably had some effect on their significance.

Animal Variation

Although only three animals were used in this study, analyses of variance indicated that there were few significant differences in the cooking and palatability factors that could be ascribed to animal variation (Table 12, Appendix). Cooking losses seemed to be affected more than the other factors.

SUMMARY

Roasts from certain muscles of the long hindquarters of three U. S. Good grade steers were studied for the effect of degree of cooking on cooking losses, shear force, press fluid yields, and

palatability factors. The long hindquarters were purchased from a Kansas City packing house and shipped to the animal husbandry meats laboratory six to eight days after slaughter. Two or three days later the following muscles were dissected, trimmed and cut into roasts: psoas major, adductor, rectus femoris, vastus lateralus, semitendinosus, longissimus dorsi (rib and loin sections), and semimembranosus (posterior and anterior sections). The longissimus dorsi and semimembranosus muscles were each divided and treated as two muscles. The roasts were wrapped in aluminum foil and frozen at -20°F. on the coil plates in a household, upright freezer. All roasts were cooked within eight weeks after freezing.

Three internal temperatures (55°, 70° and 85°C.) representing rare, medium-and well-done, were used as end-points for cooking the roasts. For the semitendinosus and longissimus dorsi (loin and rib sections) an incomplete block design, which consisted of the left and right cuts from each muscle, was used to determine the three end-temperatures of cooking. For the other muscles a randomized complete block design was used to determine the two end-temperatures.

The roasts from one paired muscle were defrosted at refrigerator temperature about 48 hours before each cooking period. The roasts were cooked in deep fat maintained at 110°C. to the desired internal temperatures. The time required for every five degree rise in the internal temperature of the meat was recorded throughout the cooking period, and the maximum internal temperature noted during the 10-minute draining period after removal from the fat. The data obtained on the cooked meat were the percent total cooking losses, shearing resistance, press fluid yields and palatability scores.

Analyses of variance were run to study the effect of the degree of cooking on cooking losses, cooking time, shear values, press fluid yields and palatability factors. When significant differences occurred among three treatments, i.e., three internal temperatures, two-way tables of means were analyzed by least significant differences. Also, correlation coefficients were determined for the tenderness scores and shear values, juiciness scores and press fluid yields, cooking losses and juiciness scores and cooking losses and press fluid yields.

The steepness of the heat penetration curves tended to lessen at 55° to 60°C. and no particular differences were noted between the rates of heat penetration in the right and left sides of the carcasses. However, the roasts from the proximal end of the muscles had slower rates of heat penetration than those from the distal end. The smaller, slender roasts, averaging about 1.0 pound, had short and fairly straight heat penetration curves; but the more blocky, compact cuts, averaging about 1.7 pounds, had longer, more sloping heat penetration curves. The internal temperature of roasts removed from the fat at 55°C. usually rose 10 to 13 degrees; those removed at 70°C., five to six degrees; and those removed at 85°C. rose only one or two degrees, if at all. Large roasts seemed more "done" than smaller roasts cooked to the same internal temperature.

Total cooking times ranged from approximately 25 to 65 minutes and the cooking time, in minutes per pound, from 22 to 48. Highly to very highly significant increases in cooking time resulted from increased internal temperatures.

During cooking the percentage weight losses always increased as the internal temperature was raised; and, in general, these differences in cooking losses were significant. Cooking losses for the roasts cooked to 55°C. were approximately 25 percent; those cooked to 70°C., approximately 31 percent; and those cooked to 85°C., approximately 35 percent. The shear values were not significantly affected by internal temperature and did not indicate consistent changes in tenderness; however, the psoas major and longissimus dorsi muscles were the most tender of the muscles tested. The press fluid yields always decreased with each increase in internal temperature. The differences in press fluid yields attributable to internal temperature were significant for all muscles except the rectus femoris, adductor and psoas major. The semitendinosus roasts yielded the most press fluid at all three temperatures. Cooking losses and press fluid yields of the meat cooked to 85°C. seemed to be more related than those of the meat cooked to 55°C. or 70°C.

Although there were only slight differences in aroma scores for cooked meat, there was a slight tendency for meat cooked to the higher internal temperatures to be scored the same as, or slightly higher than, that cooked to the lower temperature. For the most part, there were no consistent trends or significant differences in flavor scores for roasts from the muscles studied that were attributable to internal temperature. Increases in internal temperature tended to increase the tenderness scores, but the increase was not great enough to be significant. The tenderness scores and the shear force readings did not always show similar trends and were seldom significantly related. With each increase in internal temperature, the judges' scores for juiciness were lowered, some significantly, as were the press fluid yields, whereas the cooking losses were increased. Correlation coefficients for the cooking losses and juiciness scores for roasts from each muscle cooked to 55°, 70° and 85°C. indicated that there was little relationship between these factors. Also, under similar conditions little relationship was found between press fluid yields and juiciness scores. Few significant differences were found within the factors studied that could be attributed to animal variation.

CONCLUSIONS

1. Under the conditions of this study, tenderness scores and scores for tenderness preference ratings, aroma and flavor scores and shear values generally were not affected by internal temperature.
2. Increases in the internal temperature of the meat from 55° to 85°C. increased cooking times for all muscles and cooking losses for all muscles except the vastus lateralus.
3. Press fluid yields were usually decreased with increased internal temperature, but roasts from the rectus femoris, adductor, and psoas major were apparent exceptions.

4. The effect of internal temperature on juiciness scores and scores for juiciness preference ratings depended on the muscle involved.

RECOMMENDATIONS FOR FURTHER WORK

It was apparent from this study that roasts cooked in deep fat at 110°C. to an internal temperature of 55°C. (rare) were more like medium-done roasts, because the internal temperature rose to 65° to 68°C. shortly after the roasts were removed from the fat. In order to obtain a more nearly rare product, a lower cooking temperature of the fat or a lower end-point temperature in the meat may need to be used. Also, some adjustment would need to be made for the roasts cooked to 70°C.

It is possible that a clearer picture of the heat penetration curves could be obtained by plotting the curves to the maximum internal temperature after removal from the fat instead of just to the end-temperature of cooking.

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LITERATURE CITED

Bailey, K.
Tropomyosin: A new asymmetric protein component of the muscle fibril. Biochem. J. (London) 43:271-279, 1948.

Brady, D. E.
A study of the factors influencing tenderness and texture of beef. Pro. Am. Soc. Animal Prod. 30:246-250, 1937.

Child, A. M. and Mary J. Satorius.
Effect of exterior temperature upon press fluid, shear force, and cooking losses of roasted beef and pork muscles. Agri. Res. 57:865-871, 1938.

Cline, J. A., M. E. Loughead and B. C. Schwartz.
The effect of two roasting temperatures on palatability of cooking roasts. Mo. Agri. Exp. Sta. Bu. 310, 1932.

Cover, Sylvia.
Effect of metal skewers on cooking time and tenderness of beef. Food Research 6:233-238, 1941.

Cover, Sylvia.
Effect of extremely low rates of heat penetration on tendering of beef. Food Research 8:388-394, 1943.

Cover, Sylvia and W. M. Smith, Jr.
The effect of two methods of cooking on palatability scores, shear force values, and collagen content of two cuts of beef. Food Research 21(3):312-321, 1956.

Crocker, E. C.
Flavor of meat. Food Research 13:179-183, 1948.

Gaddis, A. M., O. G. Hankins and R. L. Hiner.
Relationships between the amount and composition of press fluid, palatability, and other factors of meat. Food Technol. 4:498-502, 1950.

Griswold, Ruth M.
The effect of different methods of cooking beef round of commercial and prime grades. I. Palatability and shear values. Food Research. 20(2):160-170, 1955.

Griswold, Ruth M., and Marion A. Wharton.
Effect of storage conditions on palatability of beef. Food Research 6:517-528, 1941.

Jacobson, Marion and Faith Fenton.
Effect of three levels of nutrition and age of animal on the quality of beef. I. Palatability, cooking data, moisture, fat, and nitrogen. Food Research. 21(4):415-426, 1956.

Hall, C. G., M. A. Jakus and F. O. Schmitt.
An investigation of cross striations and myosin filaments in muscle. Biol. Bul. 90:32-49, 1946.

Hall, J. Lowe, June Kalen, Beulah D. Westerman, D. L. Mackintosh and Gladys E. Vail. Keep the temperature low when storing pork. Refrig. Engg. 57:247-250, 1949.

Hankins, O. G., and R. L. Hiner.
Freezing makes beef tenderer. Food Ind. 12:49-51, 1940.

Harrison, Dorothy L., Belle Lowe, Buford R. McClurg and P. S. Shearer. Physical, organoleptic, and histological changes in three grades of beef during aging. Food Technol. 3:284-288, 1949.

Harrison, Dorothy L., Gladys E. Vail, J. L. Hall and D. L. Mackintosh. Household cooking methods for commercial grade beef. Unpublished manuscript, Kansas State College, 1953.

Hiner, R. L., E. E. Anderson and C. R. Fellers.
Amount and character of connective tissue as it relates to tenderness in beef muscle. Food Technol. 9(2):80-86, 1955.

Hiner, R. L., and O. G. Hankins.
Temperature of freezing affects tenderness of beef. Food Ind. 19:1079-1081, 1947.

Hiner, R. L., and O. G. Hankins.
The tenderness of beef in relation to different muscles and age in the animal. J. Animal Sci. 9:347-353, 1950.

Hood, Maude P., Doris W. Thompson and Lenora Mirone.
Effects of cooking methods on low grade beef. Georgia Agri. Exp. Sta. Bul. N. S. 4, 1955.

Husaini, S. A., F. E. Deatherage and L. E. Kunkle.
Studies on meat. II. Observations on relation of biochemical factors to changes in tenderness. Food Technol. 4:366-369, 1950.

Lowe, Belle.
Experimental cookery from the chemical and physical standpoint, 4th ed. p. 209-220. New York: John Wiley and Sons, Inc., 1955.

Maximow, Alexander A., and William Bloom.
A textbook of histology, 6th ed. p. 49-52, 147-153. Philadelphia: W. B. Saunders Company, 1952.

Noble, I. T., E. G. Halliday and H. K. Klaas.
Studies on tenderness and juiciness of cooked meat. J. Home Econ. 26:238-242, 1934.

Paul, Pauline, Maura Bean and L. J. Bratzler.
Effect of cold storage and method of cooking on commercial grade cow beef. Mich. Agri. Exp. Sta. Bul. 256, 1956.

Paul, Pauline and L. J. Bratzler.
Studies on tenderness of beef. II. Varying storage times and conditions. Food Research 20(6):626-634, 1955.

Paul, Pauline, L. J. Bratzler and E. D. Farwell.
The effect of method of cooking on tenderness of beef at different intervals after slaughter. J. Animal Sci. 7:519, 1948.

Pearson, A. M., and J. I. Miller.
The influence of rate of freezing and length of freezer storage upon the quality of beef of known origin. J. Animal Sci. 9:13-19, 1950.

Ramsbottom, J. M.
Freezer storage effect on fresh meat quality. Refrig. Engg. 53:19-23, 1950.

Ramsbottom, J. M. and E. J. Strandine.
Initial physical and chemical changes in beef as related to tenderness. J. Animal Sci. 8:398-410, 1949.

Ramsbottom, J. M., E. J. Strandine and G. H. Koonz.
Comparative tenderness of representative beef muscles. Food Research. 10:497-509, 1945.

Satorius, Mary J., and Alice Child.
Effect of coagulation on press fluid, shear force, muscle-cell diameter, and composition of beef muscle. Food Research. 3:619-626, 1938a.

Satorius, Mary J., and Alice Child.
Problems in meat research. I. Four comparable cuts from one animal. II. Reliability of judges scores. Food Research. 3:627-635, 1938b.

Siemers, Lorene L., and Flora Hanning.
A study of certain factors influencing the juiciness of meat. Food Research. 18(2):113-120, 1953.

Strandine, E. J., C. H. Koonz and J. M. Ramsbottom.
A study of variations in muscles of beef and chicken. J. Animal Sci. 8:483-494, 1949.

Szent-Gyorgyi, Albert.
Chemistry of muscular contraction, 2nd ed. p. 9-19, 53-54. New York: Academic Press Inc., 1951.

APPENDIX

Table 8. Weight, in grams and pounds, and cooking time, in minutes per pound.

Muscle		Int. temp. °C.	Animal number	Code	Weight Gms.	Weight Lbs.	Cooking time min./lb.
Psoas major		55	II	Al	539.0	1.2	21.7
				Bl	643.0	1.4	23.6
			IV	Ar	533.0	1.2	21.0
				Br	487.0	1.1	28.2
			V	Ar	562.0	1.2	21.9
				Br	643.5	1.4	20.5
	Av.				567.9	1.3	22.8
		70	II	Ar	492.0	1.1	27.0
				Br	682.0	1.5	27.6
			IV	Al	586.0	1.3	27.3
				Bl	488.0	1.1	33.2
			V	Al	460.0	1.0	29.0
				Bl	542.0	1.2	27.7
	Av.				541.7	1.2	28.6
Adductor		70	II	Cl	612.5	1.3	37.5
				Dr	460.0	1.0	38.0
			IV	Cr	494.0	1.1	37.7
				Dr	408.5	0.9	36.9
			V	Cl	475.0	1.0	41.5
				Dl	348.0	0.8	38.4
	Av.				466.3	1.0	38.3
		85	II	Cr	619.0	1.4	41.3
				Dl	473.0	1.0	46.0
			IV	Cl	544.0	1.2	45.6
				Dl	418.0	0.9	48.1
			V	Cr	415.0	0.9	52.2
				Dr	386.0	0.9	43.9
	Av.				475.8	1.1	46.2
Rectus femoris		70	II	Er	784.0	1.7	34.9
				Fr	623.5	1.4	31.8
			IV	El	749.5	1.7	32.9
				Fr	646.0	1.4	34.3
			V	Er	672.0	1.5	33.0
				Fr	700.0	1.5	32.8
	Av.				695.8	1.5	33.3

Table 8. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Weight Gms.	Weight Lbs.	Cooking time min./lb.
Rectus femoris	85	II	El	802.0	1.8	41.7
			Fl	688.0	1.5	39.8
		IV	Er	616.0	1.4	42.9
			Fl	683.5	1.5	39.8
		V	El	643.0	1.4	46.4
			Fl	776.0	1.7	42.9
Av.				701.4	1.6	42.3
Vastus lateralus	70	II	Gr	706.0	1.6	29.5
			Hl	853.5	1.9	26.8
		IV	Gr	670.0	1.5	29.7
			Hl	600.0	1.3	34.6
		V	Gl	506.0	1.1	31.8
			Hr	508.0	1.1	31.4
Av.				640.6	1.4	30.6
	85	II	Gl	946.5	2.1	36.4
			Hr	894.0	2.0	34.0
		IV	Gl	865.0	1.9	41.3
			Hr	702.0	1.5	41.7
		V	Gr	549.0	1.2	51.7
			Hl	741.5	1.6	40.9
Av.				783.0	1.7	41.0
Semitendinosus	55	II	Jr	504.0	1.1	29.5
			Kr	631.0	1.4	30.9
		IV	Kl	593.0	1.3	27.5
			Lr	430.0	0.9	32.2
		V	Jl	443.0	1.0	31.0
			Ll	458.0	1.0	30.0
Av.				509.8	1.1	30.2
	70	II	Jl	541.0	1.2	39.8
			Ll	491.0	1.1	36.1
		IV	Jr	503.5	1.1	37.7
			Ll	488.0	1.1	37.3
		V	Jr	428.5	0.9	41.9
			Kr	513.0	1.1	36.8
Av.				494.2	1.1	38.3

Table 8. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Weight Gms.	Weight Lbs.	Cooking time min./lb.
Semitendinosus	85	II	Kl	634.0	1.4	44.5
			Lr	475.0	1.0	47.5
		IV	Jl	470.0	1.0	50.8
			Kr	491.5	1.1	48.2
		V	Kl	517.0	1.1	51.1
			Lr	461.0	1.0	47.5
Av.				508.1	1.1	48.3
Longissimus dorsi (loin)	55	II	Mr	695.0	1.5	25.5
			Nr	662.0	1.5	21.8
		IV	Nl	633.5	1.4	18.6
			Ol	586.0	1.3	14.8
		V	Mr	660.0	1.5	26.5
			Nl	594.0	1.3	26.5
Av.				638.4	1.4	22.3
	70	II	Nl	807.0	1.8	27.9
			Or	592.0	1.3	23.3
		IV	Ml	642.0	1.4	30.5
			Or	477.0	1.1	25.7
		V	Nr	597.0	1.3	29.0
			Ol	576.0	1.3	25.2
Av.				615.2	1.4	26.9
	85	II	Ml	1026.0	2.3	30.0
			Ol	893.0	2.0	22.3
		IV	Mr	528.0	1.2	39.8
			Nr	528.0	1.2	40.2
		V	Ml	658.0	1.4	42.9
			Or	499.0	1.1	31.8
Av.				688.7	1.6	34.5
Semimembranosus (posterior)	70	II	Pr	983.5	2.2	30.3
			Qr	693.0	1.5	29.3
		IV	Pl	734.0	1.6	29.1
			Ql	591.0	1.3	30.0
		V	Pl	801.0	1.8	26.7
			Ql	716.0	1.6	24.4
Av.				753.1	1.7	28.3
	85	II	Pl	867.0	1.9	39.7
			Ql	816.0	1.8	31.9
		IV	Pr	793.5	1.7	37.4
			Qr	834.0	1.8	31.7
		V	Pr	686.0	1.5	39.0
			Qr	539.0	1.2	36.7
Av.				755.9	1.7	36.1

Table 8. (concl.)

Muscle	Int. temp. °C.	Animal number	Code	Weight Gms.	Weight Lbs.	Cooking time min./lb.
Semimembranosus (anterior)	70	II	Rl	867.0	1.9	28.4
			Sl	851.0	1.9	27.9
		IV	Rr	757.0	1.7	21.8
			Sr	518.5	1.1	27.3
		V	Rr	832.0	1.8	29.2
			Sr	822.0	1.8	28.3
Av.				774.6	1.7	27.2
	85	II	Rr	1056.0	2.3	33.5
			Sr	834.0	1.8	36.7
		IV	Rl	610.0	1.3	34.6
			Sl	716.5	1.6	32.8
		V	Rl	725.0	1.6	39.1
			Sl	830.0	1.8	36.1
Av.				795.3	1.7	35.5
Longissimus dorsi (loin)	55	II	Tl	642.0	1.4	25.7
			Ur	757.0	1.7	24.7
		IV	Tr	534.0	1.2	27.5
			Vr	723.5	1.6	24.4
		V	Tr	443.5	1.0	28.0
			Ul	485.5	1.1	26.8
Av.				597.6	1.3	26.2
	70	II	Tr	637.0	1.4	30.7
			Vl	766.0	1.7	30.7
		IV	Ul	584.0	1.3	34.4
			Vl	676.0	1.5	29.5
		V	Ur	515.5	1.1	37.3
			Vr	546.0	1.2	33.5
Av.				620.8	1.4	32.7
	85	II	Ul	806.0	1.8	36.7
			Vr	843.5	1.9	32.4
		IV	Tl	506.0	1.1	43.4
			Ur	535.0	1.2	44.2
		V	Tl	563.0	1.2	46.3
			Vl	562.0	1.2	41.3
Av.				635.9	1.4	40.7

Table 9. Total cooking losses, press fluid yields and mean palatability scores for juiciness. Maximum score possible, 10.

Muscle	Int. temp. °C.	Animal number	Code	Cooking losses	Press fluid yields	Juiciness scores
Psoas major	55	II	Al	22.8	8.0	8.1
			Bl	23.2	6.3	8.6
		IV	Ar	19.7	8.7	8.0
			Br	19.5	8.3	7.9
		V	Ar	23.8	6.9	7.5
			Br	23.7	7.5	7.4
Av.				22.1	7.6	7.9
	70	II	Ar	28.5	7.4	7.7
			Br	26.7	8.8	8.2
		IV	Al	26.6	7.3	7.9
			Bl	26.4	7.2	7.7
		V	Al	29.3	6.5	6.8
			Bl	27.5	6.3	7.5
Av.				27.5	7.3	7.6
Adductor	70	II	Cl	33.9	6.8	6.0
			Dr	33.7	6.9	6.7
		IV	Cr	32.7	7.2	5.8
			Dr	33.3	7.0	5.5
		V	Cl	33.5	5.9	5.4
			Dl	34.8	6.1	5.4
Av.				33.7	6.7	5.8
	85	II	Cr	38.9	6.1	5.7
			Dl	35.5	6.7	5.7
		IV	Cl	36.0	6.8	5.8
			Dl	37.0	6.9	5.1
		V	Cr	39.0	6.2	4.6
			Dr	39.8	5.3	5.1
Av.				37.7	6.3	5.3
Rectus femoris	70	II	Er	35.7	6.4	5.9
			Fr	33.6	8.1	6.9
		IV	El	33.0	5.5	7.2
			Fr	32.7	7.6	6.7
		V	Er	36.8	5.3	6.3
			Fr	32.6	7.1	6.6
Av.				34.1	6.7	6.6

Table 9. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Cooking losses	Press fluid yields	Juiciness scores
Rectus femoris	85	II	El	37.7	5.4	6.3
			Fl	35.5	7.3	6.4
		IV	Er	38.3	6.2	6.7
			Fl	33.9	7.3	6.6
		V	El	39.5	5.9	6.0
			Fl	40.9	4.8	5.8
Av.				37.6	6.2	6.3
Vastus lateralus	70	II	Gr	37.3	5.8	6.3
			Hl	33.1	6.6	7.0
		IV	Gr	36,1	7.1	5.7
			Hl	32.5	7.4	7.0
		V	Gl	34.3	6.4	6.7
			Hr	32.2	7.6	6.7
Av.				34.3	6.8	6.6
	85	II	Gl	38.6	5.2	5.6
			Hr	40.2	6.6	6.0
		IV	Gl	37.6	6.4	5.7
			Hr	39.2	5.9	5.6
		V	Gr	29.7	4.9	5.7
			Hl	40.9	4.5	5.2
Av.				37.7	5.6	5.6
Semitendinosus	55	II	Jr	28.4	8.6	8.5
			Kr	28.8	8.7	8.4
		IV	Kl	26.7	8.5	8.2
			Lr	25.8	8.2	7.4
		V	Jl	25.1	7.0	7.1
			Ll	26.4	8.6	7.4
Av.				26.9	8.3	7.8
	70	II	Jl	30.7	8.1	7.7
			Ll	27.7	8.0	7.6
		IV	Jr	30.0	8.1	6.4
			Ll	30.5	7.8	6.9
		V	Jr	30.2	7.4	6.6
			Kr	29.8	7.2	6.0
Av.				29.8	7.8	6.9

Table 9. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Cooking losses	Press fluid yields	Juiciness scores
Semitendinosus	85	II	Kl	36.0	7.6	6.9
			Lr	33.1	8.0	7.4
		IV	Jl	34.7	6.6	6.1
			Kr	34.9	7.0	5.7
		V	Kl	36.6	6.0	5.4
			Lr	34.9	6.3	6.3
Av.				35.0	6.9	6.3
Longissimus dorsi (loin)	55	II	Mr	26.9	7.3	8.1
			Nr	27.3	7.8	7.6
		IV	Nl	26.6	8.2	7.7
			Ol	25.7	8.9	8.0
		V	Mr	29.2	7.6	7.6
			Nl	29.1	7.0	8.1
Av.				27.5	7.8	7.9
	70	II	Nl	29.1	6.3	6.9
			Or	29.4	6.5	7.6
		IV	Ml	32.2	7.1	6.3
			Or	32.9	6.7	5.3
		V	Nr	33.8	6.5	7.3
			Ol	34.2	6.7	7.3
Av.				31.9	6.6	6.8
	85	II	Ml	33.3	6.3	6.4
			Ol	28.6	6.4	7.0
		IV	Mr	36.0	5.8	4.7
			Nr	37.9	4.7	4.9
		V	Ml	35.7	5.6	6.3
			Or	36.7	4.8	6.8
Av.				34.7	5.6	6.0
Semimembranosus (posterior)	70	II	Pr	32.8	7.5	6.4
			Qr	32.9	6.7	7.1
		IV	Pl	30.4	7.9	5.7
			Ql	34.2	7.6	6.4
		V	Pl	30.2	8.4	6.4
			Ql	32.1	7.0	7.3
Av.				32.1	7.5	6.6
	85	II	Pl	35.4	6.7	6.8
			Ql	36.4	6.4	6.8
		IV	Pr	36.9	6.9	5.0
			Qr	37.2	5.7	5.6

Table 9. (concl.)

Muscle	Int. temp. °C.	Animal number	Code	Cooking losses	Press fluid yields	Juiciness scores
Semimembranosus (posterior)	85	V	Pr	37.2	6.6	6.5
			Qr	37.1	5.7	6.0
Av.				36.7	6.3	6.1
Semimembranosus (anterior)	70	II	Rl	31.0	7.6	6.2
			Sl	33.6	6.8	5.7
		IV	Rr	30.9	8.3	6.1
			Sr	30.8	8.3	6.0
		V	Rr	36.2	6.3	6.1
			Sr	37.2	6.2	5.9
Av.				33.3	7.3	6.0
	85	II	Rr	38.5	6.7	5.2
			Sr	37.9	6.8	5.7
		IV	Rl	35.4	6.4	4.9
			Sl	35.9	6.3	5.1
		V	Rl	38.2	5.5	5.9
			Sl	40.5	5.0	6.0
Av.				37.7	6.1	5.5
Longissimus dorsi (rib)	55	II	Tl	27.6	6.9	7.8
			Ur	28.1	7.4	7.5
		IV	Tr	28.5	8.2	7.1
			Vr	28.8	8.1	6.5
		V	Tr	30.6	6.7	8.0
			Ul	27.9	7.1	7.7
Av.				28.6	7.4	7.4
	70	II	Tr	30.7	6.8	6.9
			Vl	30.4	6.2	7.1
		IV	Ul	33.4	6.4	6.1
			Vl	30.8	6.8	6.8
		V	Ur	33.5	5.9	6.7
			Vr	33.9	6.6	6.6
Av.				32.1	6.5	6.7
	85	II	Ul	35.9	6.1	5.9
			Vr	32.9	6.5	6.0
		IV	Tl	35.7	6.6	6.8
			Ur	36.7	5.7	6.1
		V	Tl	38.3	5.1	6.6
			Vl	35.4	5.9	7.1
Av.				35.8	6.0	6.4

Table 10. Mean shear values and palatability scores for tenderness, aroma and flavor. Maximum score possible, 10.

Muscle	Int. temp. °C.	Animal number	Code	Shear force value	Tenderness scores	Aroma scores	Flavor scores
Psoas major	55	II	Al	14.9	8.8	8.9	9.0
			Bl	14.9	9.4	8.7	8.6
		IV	Ar	10.0	9.3	8.1	7.7
			Br	9.6	9.3	8.4	8.0
		V	Ar	11.0	9.3	8.8	8.4
			Br	10.7	9.3	8.8	8.4
Av.				11.9	9.2	8.6	8.4
	70	II	Ar	16.6	8.9	8.8	8.9
			Br	13.5	9.2	9.0	8.9
		IV	Al	13.9	9.3	8.6	8.3
			Bl	10.9	9.1	8.4	8.1
		V	Al	12.3	9.1	8.8	8.0
			Bl	12.7	9.5	8.8	8.4
Av.				13.3	9.2	8.7	8.4
Adductor	70	II	Cl	23.2	8.3	8.6	8.6
			Dr	35.0	7.4	8.1	8.0
		IV	Cr	29.1	7.9	8.6	8.1
			Dr	42.3	7.9	8.5	8.0
		V	Cl	20.4	7.9	8.1	7.4
			Dl	20.3	8.0	8.4	7.0
Av.				28.4	7.9	8.4	7.9
	85	II	Cr	22.0	8.4	8.7	8.7
			Dl	27.2	8.1	8.3	7.7
		IV	Cl	28.3	8.1	8.5	7.8
			Dl	29.8	7.8	8.5	7.4
		V	Cr	27.0	7.6	8.3	7.0
			Dr	24.5	7.3	8.3	7.1
Av.				26.5	7.9	8.4	7.6
Rectus femoris	70	II	Er	24.3	7.4	8.1	6.7
			Fr	29.0	8.3	8.9	8.1
		IV	El	23.3	8.2	8.8	8.2
			Fr	23.3	8.0	8.7	7.3
		V	Er	17.5	8.4	8.6	8.3
			Fr	23.4	8.8	8.5	8.6
Av.				23.5	8.2	8.6	7.9

Table 10. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Shear force value	Tenderness scores	Aroma scores	Flavor scores
Rectus femoris	85	II	El	26.4	8.4	8.4	8.3
			Fl	30.5	8.1	8.4	7.7
		IV	Er	35.4	8.1	8.8	7.6
			Fl	32.5	8.2	8.8	7.9
		V	El	20.0	8.3	9.0	8.1
			Fl	12.8	8.8	8.9	8.1
Av.				26.3	8.3	8.7	8.0
Vastus lateralus	70	II	Gr	25.8	8.2	8.5	8.1
			Hl	26.9	7.8	8.5	7.9
		IV	Gr	24.8	7.9	8.4	7.5
			Hl	23.8	8.0	8.5	8.0
		V	Gl	22.6	8.2	8.0	7.6
			Hr	23.4	8.3	8.3	8.3
Av.				24.6	8.1	8.4	7.9
	85	II	Gl	27.3	8.1	8.6	7.6
			Hr	20.3	7.6	8.6	7.4
		IV	Gl	21.5	8.5	8.6	7.8
			Hr	17.4	8.1	8.3	7.5
		V	Gr	21.9	8.3	8.3	7.8
			Hl	21.3	8.6	7.9	7.4
Av.				21.6	8.2	8.4	7.6
Semitendinosus	55	II	Jr	20.5	8.0	8.3	8.1
			Kr	21.0	8.5	8.7	8.2
		IV	Kl	22.0	8.4	8.3	8.1
			Lr	21.0	8.3	8.4	8.2
		V	Jl	23.9	8.3	8.1	8.1
			Ll	21.6	8.0	8.6	8.1
Av.				21.7	8.3	8.4	8.1
	70	II	Jl	18.1	8.3	8.7	7.9
			Ll	20.7	8.1	8.5	8.3
		IV	Jr	22.6	8.3	8.4	7.9
			Ll	20.8	8.7	8.4	8.2
		V	Jr	26.7	8.3	8.3	8.6
			Kr	21.4	8.4	8.1	8.3
Av.				21.7	8.4	8.4	8.2

Table 10. (cont.)

Muscle	Int. temp. °C.	Animal number	Code	Shear force value	Tender-ness scores	Aroma score	Flavor scores
Semitendinosus	85	II	Kl	17.4	8.6	8.5	8.1
			Lr	23.7	8.3	8.9	8.5
		IV	Jl	22.7	8.6	8.6	7.9
			Kr	19.5	8.1	8.4	7.9
		V	Kl	21.8	8.4	8.6	7.9
			Lr	18.9	8.1	8.3	8.3
Av.				20.7	8.4	8.6	8.1
Longissimus dorsi (loin)	55	II	Mr	12.7	9.0	8.6	8.6
			Nr	13.1	8.5	8.3	8.3
		IV	Nl	15.3	8.6	8.3	8.0
			Ol	13.0	8.6	8.3	7.9
		V	Mr	14.0	8.9	8.5	8.9
			Nl	10.8	8.8	8.5	8.9
Av.				13.2	8.7	8.4	8.4
	70	II	Nl	14.3	8.9	8.4	8.1
			Or	13.2	8.8	8.6	8.1
		IV	Ml	21.3	8.1	8.7	7.7
			Or	19.2	8.1	8.6	7.6
		V	Nr	16.5	8.3	8.6	8.6
			Ol	18.5	8.4	8.9	8.8
Av.				17.2	8.4	8.6	8.2
	85	II	Ml	15.1	8.8	8.6	7.9
			Ol	15.2	8.5	8.4	8.0
		IV	Mr	12.6	8.6	9.1	7.9
			Nr	16.6	8.9	9.0	8.0
		V	Ml	11.3	9.0	8.5	8.5
			Or	19.7	8.5	8.6	8.4
Av.				15.1	8.7	8.7	8.1
Semimembranosus (posterior)	70	II	Pr	20.8	8.7	8.6	7.8
			Qr	32.9	7.6	8.6	8.0
		IV	Pl	22.8	9.0	8.6	8.0
			Ql	45.7	8.3	8.4	8.0
		V	Pl	21.2	8.1	8.5	8.6
			Ql	31.8	7.6	8.6	8.3
Av.				29.2	8.2	8.6	8.1
	85	II	Pl	15.9	8.6	8.9	8.3
			Ql	25.0	7.7	8.7	8.0
		IV	Pr	21.2	9.0	8.6	7.9
			Qr	30.8	8.6	8.4	7.9

Table 10. (concl.)

Muscle	Int. temp. °C.	Animal number	Code	Shear force value	Tenderness scores	Aroma scores	Flavor scores
Semimembranosus (posterior)	85	V	Pr	22.3	8.5	8.6	8.5
			Qr	37.0	8.0	8.8	8.3
Av.				25.4	8.4	8.7	8.2
Semimembranosus (anterior)	70	II	Rl	19.2	8.3	8.6	7.9
			Sl	30.5	7.4	8.9	7.8
		IV	Rr	16.8	8.4	8.7	8.3
			Sr	34.1	6.9	8.9	8.0
		V	Rr	25.2	8.4	8.5	8.0
			Sr	39.7	7.8	8.5	7.9
Av.				27.6	7.9	8.7	8.0
	85	II	Rr	27.6	8.7	8.8	7.6
			Sr	38.8	7.7	8.6	8.0
		IV	Rl	16.5	8.7	9.0	8.0
			Sl	38.6	7.9	8.9	8.0
		V	Rl	19.0	8.6	8.6	8.3
			Sl	25.1	8.0	8.8	7.9
Av.				27.6	8.3	8.8	8.0
Longissimus dorsi (rib)	55	II	Tl	13.5	8.5	8.1	8.8
			Ur	14.6	9.0	8.1	8.4
		IV	Tr	18.9	8.0	8.6	8.1
			Vr	14.9	8.1	8.6	7.9
		V	Tr	19.6	8.4	9.0	8.0
			Ul	19.1	8.6	8.4	8.6
Av.				16.8	8.4	8.5	8.3
	70	II	Tr	17.2	8.5	7.6	7.9
			Vl	16.6	9.1	8.0	8.6
		IV	Ul	14.3	8.5	9.0	7.8
			Vl	16.6	8.4	8.9	7.8
		V	Ur	17.6	8.6	9.0	8.7
			Vr	12.8	8.9	8.7	8.4
Av.				15.8	8.7	8.5	8.2
	85	II	Ul	12.2	9.4	8.3	8.4
			Vr	13.8	9.3	8.1	8.4
		IV	Tl	19.2	8.6	8.6	8.1
			Ur	13.6	8.3	8.9	7.5
		V	Tl	21.0	8.3	8.3	8.4
			Vl	12.8	8.4	9.1	8.7
Av.				15.4	8.7	8.6	8.3

Table 11. Scores assigned to judges' preference ratings for juiciness and tenderness. Low numbers indicate high preference.

Muscle	Int. temp.	Animal number	Code	Juiciness	Tenderness
Psoas major	55	II	Al	2.5	2.9
			Bl	1.8	1.9
		IV	Ar	2.4	2.3
			Br	2.8	2.7
		V	Ar	2.1	1.9
			Br	2.4	2.7
Av.				2.3	2.4
	70	II	Ar	3.1	2.9
			Br	2.6	2.2
		IV	Al	2.2	2.4
			Bl	2.6	2.6
		V	Al	3.4	3.3
			Bl	2.0	2.2
Av.				2.7	2.6
Adductor	70	II	Cl	2.4	2.4
			Dr	1.7	2.9
		IV	Cr	2.0	2.3
			Dr	2.4	2.8
		V	Cl	2.0	2.2
			Dl	2.3	2.3
Av.				2.1	2.5
	85	II	Cr	3.0	2.1
			Dl	2.9	2.7
		IV	Cl	2.3	1.8
			Dl	3.3	3.1
		V	Cr	2.9	2.3
			Dr	2.8	3.2
Av.				2.9	2.5
Rectus femoris	70	II	Er	3.5	3.2
			Fr	2.0	1.9
		IV	El	1.9	2.1
			Fr	2.6	3.1
		V	Er	2.7	2.5
			Fr	1.8	2.4
Av.				2.4	2.5

Table 11. (cont.)

Muscle	Int. temp.	Animal number	Code	Juiciness	Tenderness
Rectus femoris	85	II	El	2.4	2.6
			Fl	2.1	2.2
		IV	Er	2.9	2.5
			Fl	2.7	2.4
		V	El	2.3	3.2
			Fl	3.3	1.9
Av.				2.6	2.5
Vastus lateralus	70	II	Gr	2.3	2.1
			Hl	1.4	2.4
		IV	Gr	3.0	2.7
			Hl	1.6	2.8
		V	Gl	1.9	2.8
			Hr	2.0	2.5
Av.				2.0	2.6
	85	II	Gl	3.5	2.0
			Hr	2.8	3.5
		IV	Gl	2.6	2.1
			Hr	2.9	2.5
		V	Gr	2.9	2.5
			Hl	3.2	2.2
Av.				3.0	2.5
Semitendinosus	55	II	Jr	2.8	4.2
			Kr	2.5	3.1
		IV	Kl	1.6	3.4
			Lr	2.9	3.2
		V	Jl	2.6	3.6
			Ll	2.0	3.9
Av.				2.4	3.6
	70	II	Jl	3.9	3.9
			Ll	3.4	3.7
		IV	Jr	4.6	4.1
			Ll	3.1	3.1
		V	Jr	3.2	3.9
			Kr	4.1	2.3
Av.				3.7	3.5

Table 11. (cont.)

Muscle	Int. temp.	Animal number	Code	Juiciness	Tenderness
Semitendinosus	85	II	Kl	4.9	2.6
			Lr	3.5	3.5
		IV	Jl	3.9	2.9
			Kr	5.0	4.3
		V	Kl	5.3	3.1
			Lr	3.8	4.3
Av.				4.4	3.5
Longissimus dorsi (loin)	55	II	Mr	1.4	2.3
			Nr	3.4	4.3
		IV	Nl	2.2	2.9
			Ol	1.5	3.3
		V	Mr	2.9	3.0
			Nl	2.2	3.4
Av.				2.3	3.2
	70	II	Nl	4.3	2.6
			Or	2.9	3.6
		IV	Ml	3.5	4.1
			Or	4.8	4.3
		V	Nr	3.3	4.4
			Ol	3.3	4.4
Av.				3.7	3.9
	85	II	Ml	4.8	4.3
			Ol	3.9	4.0
		IV	Mr	4.6	3.4
			Nr	4.4	3.0
		V	Ml	4.9	1.9
			Or	4.4	3.9
Av.				4.5	3.4
Semimembranosus (posterior)	70	II	Pr	2.9	1.7
			Qr	2.3	3.3
		IV	Pl	2.1	2.2
			Ql	2.0	3.0
		V	Pl	2.6	2.5
			Ql	1.9	3.3
Av.				2.3	2.7
	85	II	Pl	2.5	1.7
			Ql	2.3	3.3
		IV	Pr	3.4	2.2
			Qr	2.5	2.6

Table 11. (concl.)

Muscle	Int. temp.	Animal number	Code	Juiciness	Tenderness
Semimembranosus (posterior)	85	V	Pr	2.7	1.8
			Qr	2.8	2.4
Av.				2.7	2.3
Semimembranosus (anterior)	70	II	Rl	2.1	2.2
			Sl	2.3	3.1
		IV	Rr	1.9	2.1
			Sr	2.1	3.9
		V	Rr	2.4	2.3
			Sr	3.0	2.9
Av.				2.3	2.8
	85	II	Rr	3.2	1.7
			Sr	2.4	3.1
		IV	Rl	3.1	1.7
			Sl	2.9	2.3
		V	Rl	2.4	2.1
			Sl	2.3	2.8
Av.				2.7	2.3
Longissimus dorsi (rib)	55	II	Tl	2.6	5.1
			Ur	3.0	3.1
		IV	Tr	2.5	4.5
			Vr	3.4	3.5
		V	Tr	2.2	3.2
			Ul	2.2	3.6
Av.				2.7	3.8
	70	II	Tr	3.7	4.6
			Vl	2.6	2.9
		IV	Ul	4.5	2.8
			Vl	3.1	3.6
		V	Ur	4.1	3.5
			Vr	4.4	2.6
Av.				3.7	3.3
	85	II	Ul	4.5	1.9
			Vr	4.6	3.2
		IV	Tl	3.0	2.6
			Ur	4.4	4.0
		V	Tl	4.4	4.4
			Vl	3.7	3.8
Av.				4.1	3.3

Table 12. Summary of analyses of variance for the effect of animal difference on the cooking and palatability factors.

Muscle	Cooking losses	Cooking time	Tenderness Score	Tenderness Shear Value	Tenderness Pref.	Juiciness Score	Juiciness Press Fluid	Juiciness Pref.	Aroma	Flavor
Psoas major	ns	**	ns	*	ns	*	ns	ns	ns	ns
Adductor	ns	ns	ns	ns	ns	*	*	ns	ns	**
Rectus femoris	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Vastus lateralus	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Semimembranosus (posterior)	ns	ns	**	ns	*	ns	ns	ns	ns	ns
Semimembranosus (anterior)	*	ns	*	ns	ns	ns	ns	ns	ns	ns
Semitendinosus	**	*	ns	ns	ns	**	ns	ns	ns	ns
Longissimus dorsi (loin)	*	ns	ns	ns	ns	ns	ns	ns	ns	**
Longissimus dorsi (rib)	**	*	*	**	ns	ns	*	ns	ns	ns

ns - non-significant
* - significant
** - highly significant

Table 13. Mean squares and significance for cooking factors.

Source of variation	D/F	Cooking losses	Cooking time	Shear values	Press fluid yields
Psoas major					
Animal	5	4.24 ns	12.74 **	8.06 *	.53 ns
Temperature	1	86.94 ***	101.50 ***	6.46 ns	.41 ns
Error	5	1.08	.80	1.45	1.06
Total	11				
Adductor					
Animal	5	2.67 ns	12.39 ns	60.77 ns	.56 *
Temperature	1	49.21 ***	184.87 **	11.02 ns	.30 ns
Error	5	.96	4.13	25.83	.08
Total	11				
Rectus femoris					
Animal	5	6.02 ns	3.37 ns	54.63 ns	1.68 ns
Temperature	1	38.16 *	241.21 ***	23.52 ns	.80 ns
Error	5	3.70	3.96	30.93	.63
Total	11				
Vastus lateralus					
Animal	5	8.51 ns	31.37 ns	7.88 ns	.59 ns
Temperature	1	35.71 ns	322.41 **	25.82 ns	4.56 *
Error	5	12.47	12.59	5.09	.58
Total	11				
Semimembranosus (post.)					
Animal	5	1.17 ns	6.59 ns	124.81 ns	.45 ns
Temperature	1	63.48 **	180.97 **	44.09 ns	4.20 **
Error	5	1.73	10.75	25.11	.19
Total	11				

Table 13. (concl.)

Source of variation	D/F	Cooking losses	Cooking time	Shear values	Press fluid yields
Semimembranosus (ant.)					
Animal	5	9.95 *	8.49 ns	126.84 ns	1.14 ns
Temperature	1	59.41 **	207.50 ***	0.00 ns	3.86 *
Error	5	1.71	4.14	41.14	.28
Total	11				
Semitendinosis					
Animal	8	7.24 **	26.60 *	7.17 ns	.61 ns
Temperature	2	82.88 ***	401.82 ***	3.14 ns	2.55 **
Error	7	.76	4.96	2.63	.19
	17				
Longissimus dorsi (loin)					
Animal	8	12.00 *	48.82 ns	8.36 ns	.61 ns
Temperature	2	65.16 **	198.90 **	15.70 ns	5.87 **
Error	7	3.22	18.11	7.53	.46
Total	17				
Longissimus dorsi (rib)					
Animal	8	9.21 **	37.47 *	13.91 **	.61 *
Temperature	2	56.32 ***	234.19 ***	2.30 ns	2.34 **
Error	7	.79	5.71	1.84	.12
Total	17				

Table 14. Mean squares and significance for palatability scores and preferences.

Source of variation	D/F	Aroma	Flavor	Juiciness		Tenderness	
				Pref.	Score	Pref.	Score
Psoas major							
Animal	5	.11 ns	.30 ns	.16 ns	.37 *	.17 ns	.07 ns
Temperature	1	.04 ns	.02 ns	.30 ns	.24 ns	.12 ns	.01 ns
Error	5	.03	.06	.23	.04	.21	.02
Total	11						
Adductor							
Animal	5	.05 ns	.66 **	.13 ns	.41 *	.27 ns	.13 ns
Temperature	1	.01 ns	.17 ns	1.51 **	.66 *	.01 ns	.00 ns
Error	5	.03	.04	.05	.07	.13	.11
Total	11						
Rectus femoris							
Animal	5	.09 ns	.22 ns	.18 ns	.24 ns	.28 ns	.19 ns
Temperature	1	.04 ns	.02 ns	.12 ns	.27 ns	.01 ns	.05 ns
Error	5	.06	.37	.44	.09	.18	.10
Total	11						
Vastus lateralus							
Animal	5	.08 ns	.02 ns	.20 ns	.17 ns	.19 ns	.13 ns
Temperature	1	.00 ns	.30 ns	2.71 **	2.61 **	.02 ns	.06 ns
Error	5	.03	.11	.23	.15	.18	.04
Total	11						
Semimembranosus (post.)							
Animal	5	.03 ns	.12 ns	.10 ns	.66 ns	.68 *	.52 **
Temperature	1	.04 ns	.01 ns	.48 ns	.57 ns	.33 ns	.10 ns
Error	5	.01	.03	.20	.19	.08	.02
Total	11						

Table 14. (concl.)

Source of variation	D/F	Aroma	Flavor	Juiciness		Tenderness	
				Pref.	Score	Pref.	Score
Semimembranosus (ant.)							
Animal	5	.03 ns	.05 ns	.03 ns	.08 ns	.64 ns	.54 *
Temperature	1	.03 ns	.00 ns	.52 ns	.86 ns	.66 ns	.48 *
Error	5	.03	.03	.27	.16	.17	.05
Total	11						
Semitendinosus							
Animal	8	.04 ns	.05 ns	.77 ns	1.05 **	.51 ns	.06 ns
Temperature	2	.02 ns	.01 ns	4.42 **	2.40 **	.02 ns	.02 ns
Error	7	.05	.04	.46	.12	.25	.03
Total	17						
Longissimus dorsi (loin)							
Animal	8	.06 ns	.282 **	.40 ns	.86 ns	.57 ns	.10 ns
Temperature	2	.06 ns	.160 *	7.98 ***	4.85 **	.08 ns	.04 ns
Error	7	.05	.031	.34	.33	.76	.07
Total	17						
Longissimus dorsi (rib)							
Animal	8	.30 ns	.22 ns	.55 ns	.32 ns	.80 ns	.26 *
Temperature	2	.00 ns	.02 ns	2.20 ns	1.12 ns	.46 ns	.06 ns
Error	7	.10	.08	.57	.25	.56	.05
Total	17						

SCORE CARD FOR BEEF

JUDGE ________ CODE ________ DATE ________

Sample number	Aroma	Flavor	Juiciness	Tenderness	Number of chews	Comments
1.						
2.						
3.						
4.						
5.						
6.						

Descriptive Terms for Scoring:

10. Extremely good
9. Very good
8. Good
7. Moderately good
6. Slightly good
5. Slightly poor
4. Moderately poor
3. Poor
2. Very poor
1. Extremely poor

Rate Samples According to Preference:

For Tenderness	For Juiciness
1. ________	1. ________
2. ________	2. ________
3. ________	3. ________
4. ________	4. ________
5. ________	5. ________
6. ________	6. ________

THE PALATABILITY OF CERTAIN BEEF MUSCLES COOKED IN DEEP FAT TO THREE DEGREES OF DONENESS

by

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There is a need for more information regarding the palatability of different parts of the beef carcass that have been cooked to several degrees of doneness. Generally, it is believed that muscle fibers become less tender as the protoplasmic proteins coagulate, whereas the collagenous connective tissue is softened and partially hydrolyzed with extended heating. Under certain conditions the changes in the connective tissue during cooking may increase the tenderness of the cooked meat more than the coagulation of muscle fiber proteins decreases tenderness.

In view of the limited data relative to the effect of degree of doneness on the palatability of beef, it seemed worthwhile to design a study in which tender and less tender muscles were cooked rare, medium- and well-done. Therefore, in the study reported here, organoleptic and physical tests were used to evaluate the palatability of certain muscles cooked in deep fat to internal temperatures of 55°, 70° and $85\ ^{\circ}C$.

Roasts from certain muscles of the long hindquarters of three U. S. Good grade steers were studied for the effect of degree of cooking on cooking losses, shear force, press fluid yields, and palatability factors. The long hindquarters were purchased from a Kansas City packing house and shipped to the animal husbandry meats laboratory six to eight days after slaughter. Two or three days later the following muscles were dissected, trimmed and cut into roasts: psoas major, adductor, rectus femoris, vastus lateralus, semitendinosus, longissimus dorsi (rib and loin sections), and semimembranosus (posterior and anterior sections). The longissimus dorsi and semimembranosus muscles were each divided and treated as two muscles. The roasts were wrapped in aluminum foil and frozen at -20°F. on the coil plates in a household, upright freezer. All roasts were cooked within eight weeks after freezing.

Three internal temperatures (55°, 70° and 85°C.) representing rare, medium- and well-done, were used as end-points for cooking the roasts. For the semitendinosus and longissimus dorsi (loin and rib sections) an incomplete block design, which consisted of the left and right cuts from each muscle, was used to determine the three end-temperatures of cooking. For the other muscles a randomized complete block design was used to determine the two end-temperatures.

The roasts from one paired muscle were defrosted at refrigerator temperature about 48 hours before each cooking period. The roasts were cooked in deep fat maintained at 110°C. to the desired internal temperatures. The time required for every five degree rise in the internal temperature of the meat was recorded throughout the cooking period, and the maximum internal temperature noted during the 10-minute draining period after removal from the fat. The data obtained on the cooked meat were the percent total cooking losses, shearing resistance, press fluid yields and palatability scores.

Analyses of variance were run to study the effect of the degree of cooking on cooking losses, cooking time, shear values, press fluid yields and palatability factors. When significant differences occurred among three treatments, i.e., three internal temperatures, two-way tables of means were analyzed by least significant differences. Also, correlation coefficients were determined for the tenderness scores and shear values, juiciness scores and press fluid yields, cooking losses and juiciness scores and cooking losses and press fluid yields.

The steepness of the heat penetration curves tended to lessen at 55° to 60°C. and no particular differences were noted between the rates of heat penetration in the right and left sides of the carcasses. However, the roasts from the proximal end of the muscles had slower rates of heat penetration than those from the distal end. The smaller, slender roasts, averaging about 1.0 pound, had short and fairly straight heat penetration curves; but the more blocky, compact cuts, averaging about 1.7 pounds, had longer, more sloping heat penetration curves. The internal temperature of roasts removed from the fat at 55°C. usually rose 10 to 13 degrees; those removed at 70°C., five to six degrees; and those removed at 85°C. rose only one or two degrees, if at all. Large roasts seemed more "done" than smaller roasts cooked to the same internal temperature.

Total cooking times ranged from approximately 25 to 65 minutes and the cooking time, in minutes per pound, from 22 to 48. Highly to very highly significant increases in cooking time resulted from increased internal temperatures.

During cooking the percentage weight losses always increased as the internal temperature was raised; and, in general, these differences in cooking losses were significant. Cooking losses for the roasts cooked to 55°C. were approximately 25 percent;

those cooked to 70°C., approximately 31 percent; and those cooked to 85°C., approximately 35 percent. The shear values were not significantly affected by internal temperature and did not indicate consistent changes in tenderness; however, the psoas major and longissimus dorsi muscles were the most tender of the muscles tested. The press fluid yields always decreased with each increase in internal temperature. The differences in press fluid yields attributable to internal temperature were significant for all muscles except the rectus femoris, adductor and psoas major. The semitendinosus roasts yielded the most press fluid at all three temperatures. Cooking losses and press fluid yields of the meat cooked to 85°C. seemed to be more related than those of the meat cooked to 55° or 70°C.

Although there were only slight differences in aroma scores for cooked meat, there was a slight tendency for meat cooked to the higher internal temperatures to be scored the same as, or slightly higher than, that cooked to the lower temperature. For the most part, there were no consistent trends or significant differences in flavor scores for roasts from the muscles studied that were attributable to internal temperature. Increases in internal temperature tended to increase the tenderness scores, but the increase was not great enough to be significant. The tenderness scores and the shear force readings did not always show similar trends and were seldom significantly related. With each increase in internal temperature, the judges' scores for juiciness were lowered, some significantly, as were the press fluid yields, whereas the cooking losses were increased. Correlation coefficients for the cooking losses and juiciness scores for roasts from each muscle cooked to 55°, 70° and 85°C. indicated that there was little relationship between these factors. Also, under similar conditions little relationship was found between press fluid yields and juiciness scores. Few significant differences were found within the factors studied that could be attributed to animal variation.