INFLUENCE OF "HOT" BONING ON BOVINE MUSCLE

By

CURTIS LYNN KASTNER

Bachelor of Science
Oklahoma State University
Stillwater, Oklahoma
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Master of Science
Oklahoma State University
Stillwater, Oklahoma
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Thesis Approved:

Robert L. Henrickson
Thesis Adviser

George W. Newell

H. C. Olson

Robert D Morrison

George V. Odell

D Durham
Dean of the Graduate College

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CHAPTER I

INTRODUCTION

Processing meat prior to chilling is of commercial interest; consequently, extensive research has been conducted on porcine muscle. Bovine muscle has received limited attention; thus, a meaningful research project would consist of evaluating "hot" boning of beef carcasses.

Fabrication of the beef carcass prior to chilling has several potential advantages. The economy of this process is reflected by the fact that waste fat and bone are removed prior to chilling; thus, the possibility of conserving on cooler space and total refrigeration input is apparent. A boneless, closely trimmed product, as would be produced by "hot" boning, could lend itself well to portion control and marketability. In addition, processing time might possibly be reduced.

The objective of this study is to evaluate the feasibility of "hot" boning of beef carcasses with respect to product yield, juiciness, tenderness, flavor, and color.

CHAPTER II

REVIEW OF LITERATURE

Physical Characteristics of Muscle

Muscle Structure

Muscle is surrounded by a connective tissue layer called the epimysium, from the deep surface of which septa pass into the muscle at irregular intervals. The perimysium consists of these septa which surround bundles of muscle fibers (cells). Delicate extensions of fine connective tissue strands pass from the perimysium to surround each muscle fiber. This connective tissue division is known as the endomysium. Even though the connective tissue septa have these divisions by name, this structure is continuous among all connective tissue strands and the tendons of origin and insertion of that particular muscle (Briskey 1967a). Surrounding each fiber and underneath the endomysium is the cell membrane (sarcolemma) which was once thought to be structureless. With the aid of the electron microscope, it has been shown that the sarcolemma consists of layers (Robertson 1957). Lorincz and Biro (1963) reported that there was a collagenous type structure (reticular fibers) between the endomysium and the sarcolemma.

The adult muscle fiber is approximately 10-100 microns in diameter. The fiber consists of long unbranching threads of protein (myofibrils) which parallel the long axis of the fiber. Myofibrils are striated and

adjacent myofibrils lie with their light and dark bands in register giving the fiber a striated appearance (Briskey 1967a). Bendall (1966) reported that the average muscle cell with a diameter of 50 microns contained approximately 2000 myofibrils (1 micron in diameter). The myofibrils have no membrane, but retain their structural integrity because they are insoluble at the ionic strength of the cell. The myofibrils may also be held together by the endoplasmic reticulum, which may aid in keeping the myofibril striations in register. Functional units of the muscle cell are the sarcomeres which are bounded on each end by a "Z" line (Briskey 1967a). Huxley (1953) indicated that within the sarcomere the dense "A" band consisted of thick filaments, approximately 100 angstroms in diameter and 1.5 microns in length, which primarily contained the protein myosin. Huxley (1957a) found that the light or "I" band consisted of thin filaments of the protein actin. This band was 1 or 2 microns in length depending on whether filament length on both sides of the "Z" line was considered. The cross bridge attachments between the thick (primarily myosin) and thin (primarily actin) filaments have been shown to be a part of the myosin molecule. Tropomyosin B (Bailey type) may be present in the "Z" line and also partially in the thin filament of the "I" band. Huxley and Hanson (1960) reported that the light area in the center of the "A" band where the actin filament stops was the "H" zone. This zone widened when the fibril was in a stretched state and closed as it contracted. Below resting length the "I" substance showed no change in length until the "H" zone disappeared, and then it shortened. Upon shortening a dense line, referred to as the "M" line, appeared in the center of the sarcomere as if the actin filaments were crumpling on their ends.

The sarcoplasm of the muscle fiber is essentially an undifferentiated mass of protoplasm. The function of the sarcoplasm is thought to be one of nutrient support for the myofibrils. Certain formed structures are found in the sarcoplasm: the mitochondria, the sarcoplasmic lipid bodies, and the sarcoplasmic reticulum or tubular system which is involved in ion release and uptake during the muscle contraction and relaxation. A golgi apparatus also can usually be found in the sarcoplasm. The sarcoplasmic reticulum was entirely a sarcoplasmic component not seen within the myofibrils. It had connections with the "Z" lines, less regularly with the "M" lines and was also found in close association with the mitochondria (Walls 1960). This is not to say that all the cell components have been enumerated. For example, the lysosomes exist within the muscle fiber and are thought to be involved in proteolysis. In addition, striated skeletal muscle is multinucleated.

Muscle Proteins

Twenty percent of the wet weight of the mammalian muscle is protein, but this amount is extremely variable and is influenced by muscle type (fast or slow glycolizing), training, and stage of post-natal life. There are three classes of proteins in skeletal muscle: (1) stroma proteins which are connective tissue proteins that serve a role of support, (2) sarcoplasmic proteins which are glycolytic enzymes and pigments, and (3) myofibrillar proteins which are the contractile protein fraction (Perry 1965).

The author is primarily concerned with the proteins involved in contraction and rigor mortis. Even though stroma proteins partially control the extent of contraction, their active involvement in contrac-

tion has not been demonstrated and seems quite unlikely. Therefore, this review will not encompass connective tissue proteins. The sarcoplasmic proteins and their involvement in contraction is unlikely, but these proteins do change in quality upon contraction, training, or aging, and they undoubtedly penetrate the myofibril. It would be unwise to entirely exclude the possibility that a minor fiber component has an effect on muscle contraction (Perry 1965). Consequently, the sarcoplasmic proteins are discussed in limited detail.

Sarcoplasmic Proteins. The sarcoplasmic proteins exist as soluble molecules in the cytoplasm of the muscle fiber. Striated rabbit muscle contained 20-30 percent of total muscle protein as sarcoplasmic protein (Perry 1956). Lawrie (1966a) stated that sarcoplasmic proteins represented a complex of about 50 components. Many of these proteins were enzymes peculiar to glycolysis. Sarcoplasmic proteins are easily denatured whether it be via heat, pH, or ionic strength; consequently, they lose their water holding capacity upon denaturation. Johnson (1969a) reported that sarcoplasmic proteins were relatively easily extracted when compared to myofibrillar proteins and were frequently mentioned as the "soluble proteins" of muscle. The same author found that sarcoplasmic proteins could be brought into solution readily with water or with neutral salt solutions of low ionic strength, and the sarcoplasmic proteins when removed left the myofibril integrity apparently unaltered.

The remaining discussion of muscle proteins is devoted to myofibrillar proteins. Briskey (1967a) pointed out that several myofibrillar proteins have been identified by various workers. These are myosin, actin, tropomyosin, actomyosin, α-actinin, B-actinin, and troponin. This

review deals with myosin, actin, tropomyosin, and actomyosin because these proteins and their role in muscle is more clearly understood than the function and action of the recently discovered proteins. This is not to say that myosin, actin, tropomyosin, and actomyosin are completely understood nor does the author wish to discount the importance of α-actinin, B-actinin, and troponin, but their discussion is beyond the scope of this review.

Myosin. Myosin is the most abundant of the myofibrillar proteins and composes approximately 38 percent of the muscle protein (Giffee et al. 1960). Frandson (1966) reported that each myofibril contained about 2500 myosin filaments, and Bendall (1969) indicated that each myosin filament consisted of 180 or 360 myosin molecules. Lowey and Cohen (1962) found the myosin molecule was made of a rod shaped helical coil, and Rice (1961) found that the molecule measured 1600 angstroms long and 15-40 angstroms in diameter.

The myosin molecule can be divided into two fragments which are called meromyosins; the head being the "heavy" meromyosin and the rod-like tail the "light" meromyosin. The molecular weight, when both "heavy" and "light" meromyosin fragments were considered, was approximately 500,000; the "heavy" meromyosin making up the largest portion of the molecule weight. The "heavy" meromyosin could be the projection described by many authors as that which attaches itself to the actin filament during contraction (Szent-Györgi 1953). Enzyme activity (ATP-ase) was also associated with the "heavy" meromyosin (Szent-Györgi 1953 and Rice 1964).

Harrow and Mazur (1966) and Giffee et al. (1960) found myosin capable of binding calcium and potassium, and that magnesium was normally

bound to the myosin molecule. Myosin has a relatively high charge because it contains large amounts of glutamic and aspartic acid and some dibasic amino acids.

Actin. Giffee et al. (1960) further reported that actin plus myosin formed the principal contractile component of muscle and that actin represented about 13 percent of the total muscle protein. The actin to myosin ratio was approximately 1:3.

According to Bailey (1954) actin can exist in two forms, globular or fibrous. Fibrous (F-actin) is that form which associated with myosin to produce actomyosin during contraction in pre-rigor muscle or the inextensible actomyosin of muscle in rigor mortis. Globular actin (G-actin) had a molecular weight of about 70,000. F-actin consisted of the globular units aggregated end-to-end to form a double chain (Lawrie 1966b). Briskey (1967b) noted that G-actin polymerized to F-actin to form a linear aggregate to give an F-actin strand with a molecular weight of several million. This strand was a double helix such that the overall diameter was about 80 angstroms.

Actomyosin. Actin and myosin interact to form actomyosin. The nature of the interaction is still not completely understood, but the formation of actomyosin is vitally important to the function of muscle when used as a food. The formation of actomyosin (post-mortem) in the absence of ATP resulted in the onset of rigor mortis (Briskey 1967b). Bendall (1951) observed that the loss of extensibility (post-mortem), which reflected actomyosin formation, proceeded slowly at first (delay period) then proceeded rapidly (fast phase).

Tropomyosin. Tropomyosin resembles myosin in its solubility prop-

erties, amino acid composition, and iso-electric point. The helical structure of tropomyosin resembles "light" meromyosin. The molecular weight is about 50,000 and in the presence of low ionic concentrations it polymerizes end-to-end to form hexamers which give a length-to-width ratio of about 20:1 for the individual particles (Briskey 1967b). Huxley (1957b) suggested that tropomyosin laid in the grooves of the double helix of G-actin monomers. It was thought to run the entire length of the thin filament or stop at the "A" - "I" junction. Possibly the tropomyosin continues through the "Z" line as single strands and not in its "normal" helical structure.

Rigor Mortis

Once muscle has been converted to meat is the reviewer's major concern, but pre-slaughter conditions can affect the rate of rigor mortis and the quality of the finished product. For example, moisture loss may be caused by hunger or fatigue prior to slaughter, but such a change is not drastic in beef. Inadequate feeding and exhaustive exercise can cause glycogen depletion, a high ultimate pH, and changes in the severity and extent of rigor mortis in the finished product. These are just a few of the ramifications of pre-slaughter handling and are not intended to be all inclusive.

Bendall (1951), Marsh (1954), and Partmann (1963) observed that physiological contraction and rigor mortis were basically the same, but in later work by Bendall (1960) it was shown that shortening, in rigor mortis, involved only a fraction of the muscle fibers and was irreversible; thus, rigor mortis was distinguished from physiological contraction.

Upon exsanguination of the animal, the efficient production of

adenosine triphosphate (ATP) from glycogen via respiration gave way to inefficient anaerobic glycolysis (Lawrie 1966c). The main chemical changes after death in the muscle according to Briskey (1959) were the production of lactic acid from anaerobic glycolysis, and the breakdown of creatine phosphate which served as a mechanism for resynthesis of ATP from ADP. Infante and Davies (1962) observed that the onset of shortening in rigor mortis, after the release of Ca^{++} into the sarcoplasm, could be attributed to cyclic formation and breakage of actin and myosin cross-links which were accompanied by enzymatic hydrolysis of ATP by calcium activated actomyosin ATP-ase. Rigor mortis continued to develop until ATP was depleted. After death the ATP-ase activity of the muscle fiber continued to rapidly deplete the ATP. This was true because net ATP production from respiration and glycolysis was inhibited and resynthesis of ATP via creatine phosphate was stopped in that creatine phosphate levels were reduced. As the ability to produce ATP was altered, the cross-links which were once able to break and reform no longer had the energy source to perform relaxation and contraction; thus, the muscle became inelastic.

Within the sarcoplasm there exists an ATP-ase (soluble) which reacts slowly as compared to myosin ATP-ase, but it is responsible for the small degree of contraction necessary to maintain muscle tone and body temperature. This process utilizes residual ATP, and as dephosphorylation exceeds rephosphorylation the ATP level drops and rigor mortis ensues (Bendall 1951).

The contractile structure and sliding mechanism of striated muscle, including the overlapping filaments containing primarily actin and myosin, has been discussed by Huxley and Hanson (1960). Actin filaments extend

to the "Z" line, which is the boundary of the sarcomere, and slide back and forth on the "A" band filaments (myosin). Cross sections of the "A" band showed each myosin filament surrounded by six actin filaments. Sarcomere length was altered as the myosin and actin filaments slid past each other to form the actomyosin complex, which was formed by cross bridge attachements between the two proteins. The same authors found the "A" band to remain of a constant length as the rabbit psoas fibrils shortened while the "I" band changed in length. When the rabbit psoas fibril shortened to about 65 percent of resting length, the "I" band completely disappeared, and each "Z" line touched the end of two adjacent "A" bands. The "H" zone stretched and closed as the filament contracted. Below resting length, the "I" substance showed no change in length until the "H" zone had disappeared and then it shortened, but a dense line appeared in the middle of the sarcomere as though the actin filaments had crumpled on their ends. This was probably the "M" line described by previous workers (Huxley and Hanson 1960).

Rigor mortis onset, as defined by the rigorometer, was found by Briskey et al. (1962) to vary from two minutes to eight hours in porcine muscle. The differences were due to: (1) variation in membrane resistance against autolytic processes or acidification, (2) deviations in post-mortem release of calcium and other ions by muscle proteins, (3) differences in the relation between the velocity of glycolytic ATP resynthesis and its breakdown. All glycolytic processes should be completed 36 hours post-mortem in beef muscle (Marsh 1954). Smith et al. (1969) found that shortening due to rigor mortis was complete within three hours in chicken and five hours in turkey muscle. Complete loss of extensibility in turkey pectoralis muscle was accomplished 25-390

minutes post-mortem (T-I Ma et al. 1971). Sayre and Briskey (1963) used the rigorometer devised by Briskey to measure the time course of rigor mortis in porcine muscle. In the animals tested, rigor was completed within five hours after exsanguination. The pH decline in muscle (post-mortem) has been used to follow the time course of rigor mortis (Khan 1971 and Marsh 1954). Marsh (1954) also stated that the onset of rigor mortis coincided with the rapid phase of ATP breakdown and this decomposition was directly related to pH change over time when the ultimate pH was low. The same author created a chart to predict when rigor was complete if the ambient temperature and muscle pH were known. Defremery and Pool (1960) observed that rapid stiffening in chicken muscle did not begin until the ATP content of the muscle reached about 30 percent of its initial concentration. After the ATP declined to a minimum value, toughening occurred. Not only did rigor mortis rates vary from animal to animal but also from muscle to muscle within the ox (Locker 1960). As the muscle proceeds toward "complete" rigor mortis the eating quality of the muscle is reduced and the degree of reduction is dependent upon the severity and extent of rigor.

Temperature and Rigor Mortis. Environmental temperature immediately post-mortem has a marked influence on the extent and severity of rigor mortis, muscle shortening, and tenderness of the finished product. Wilson et al. (1960) found the shortening of beef muscle to be much greater at 0 - 15°C than at higher temperatures (20 - 43°C), but the accelerated aging to be expected at higher temperatures might well have obscured any toughening produced during rigor onset at an elevated temperature. Minimum shortening in fresh ox muscle was observed by Locker and Hagyard (1963) when the ambient temperature during the time courses

of rigor mortis was 14 - 19°C. Porcine muscle allowed to undergo rigor mortis at 2°C was significantly less tender and shortened more than similar samples held at 16°C (Forrest et al. 1969). Sarcomere length was used by Smith et al. (1969) to evaluate "cold shortening" in avian muscle held at selected temperatures, and they found shortening was minimal at 12 - 18°C and maximum at 20°C.

Excision of the Longissimus dorsi muscle prior to rigor and subjection to cold environment caused extensive shortening and resultant toughness in lamb (Marsh and Leet 1966). DeFremery and Pool (1960) observed that ATP breakdown and toughness in excised chicken breast muscle followed the same general pattern and was minimal in the 10 - 20°C temperature range.

The time required for rigor mortis was 57 percent less at 43°C than at 37°C (Briskey et al. 1962). Other studies on the time course of rigor mortis in ox muscle, (Cassens and Newbold 1967), showed that the delay phase of rigor mortis increased as the temperature was decreased from 37°C to 15°C, but this phase decreased as the temperature was decreased from 15°C to 1°C. Rigor commenced more quickly at 1°C than at 37°C. A possible explanation for reduced cold shortening at temperatures around 16°C was given by Levy et al. (1962). Myosin (ATP-ase) enzymatic properties were altered at 16°C which reflected a change in the shape of the enzymic site of the molecule at this temperature which was approximately that of minimum muscle shortening. Sink et al. (1965) noted that when the delay phase of rigor mortis was of short duration shortening, at the onset of rigor mortis, was quite severe, but when the delay phase of rigor was of long duration, the sarcomere shortening was somewhat less. Therefore, the time course of rigor mortis dictates the amount of

sarcomere shortening and resulting product tenderness.

"Thaw rigor" is a phenomenon which occurs when meat frozen prior to rigor mortis is thawed (Marsh et al. 1968 and Perry 1950). Thirty-six hours post-mortem was sufficient time to allow before freezing to insure no "thaw rigor" in beef muscle (Marsh 1954). Marsh and Thompson (1958) found that muscles frozen pre-rigor and thawed under tension did not shorten. As the thawing temperature increased so did the drip loss from pre-rigor frozen lamb Longissimus dorsi muscle.

Water-Holding Capacity and Rigor Mortis. Water-holding capacity of the muscle is reduced at the onset of rigor mortis. Denaturation of the sarcoplasmic proteins reduces the water binding ability of the muscle fiber and if the ultimate pH is 5.4 - 5.6 the proteins approach their iso-electric point. Water-binding capacity of a protein is minimal at the iso-electric point, and water-holding capacity is lower than in vivo even if there is no denaturation (Lawrie 1966d).

Pre-Rigor Excision and Tension. Herring et al. (1965a) demonstrated that bovine muscles excised pre-rigor were more tender when tension was applied during the course of rigor mortis. Lowe and Stewart (1946) noticed that breast muscle of chicken excised soon after death was usually less tender than the intact side. The faster the muscle was removed after death the less tender the product, but if rigor had developed prior to excision no additional toughening was observed. T-I Ma et al. (1971) noted that the less ATP present the smaller the effect of muscle excision on tenderness. Beef chilled in the carcass was more tender than beef which was boned and chilled to 1.67°C (Ramsbottom and Strandine 1949). The same authors observed that muscle was more tender

two hours post-mortem than after six hours of aging. However, beef that was aged 12 days was more tender than beef sampled two hours post-mortem. Beef Semitendinosus muscle held at 2°C and 24°C increased to a maximum tension during rigor then declined. For the data given the tension decline was minimal at about 95 hours post-mortem (Jungk et al. 1967). Using the same muscle, Goll et al. (1964) found that muscles left attached to the skeleton were least tender immediately post-mortem and gradually increased in tenderness during aging. Excised muscles in this study were least tender 6-12 hours after death and tenderness increased during aging. Even after 312 hours of aging the excised muscles were less tender than the muscles left on the skeleton. The effect of induced tension on pre-rigor excised muscles was studied by Gillis and Henrickson (1968). They found a decrease in muscle fiber diameter with an increase in tension up to 1,000 grams. Muscle fiber distortion decreased as tension on the muscle increased, and as fiber distortion increased so did shear force. Reddy (1962) subjected bovine Longissimus dorsi and Gluteus medius muscles to pre-rigor excision and found fiber diameter and shear force not to be significantly affected when compared to post-rigor excised muscles. However, the same author observed significant increases in pre-rigor excised Semitendinosus muscle when shear force and fiber diameter were evaluated. Fiber diameter was correlated to shear force. Herring et al. (1965b) found correlation coefficients of 0.82 - 0.87 between fiber diameter and shear force which indicated that larger fibers were less tender.

Proteolysis and Rigor Mortis. For several years controlled muscle deterioration or aging has been used to increase tenderness. Shear values increase as rigor mortis proceeds, but post-rigor aging increases

tenderness. This increase in tenderness was probably not due to actomyosin disassociation nor proteolysis of the myofibrillar proteins (Lawrie 1966e). The same author stated that increased tenderness could not be attributed to extensive proteolysis of connective tissue, but it was suggested that the actin filaments detach from the "Z" line resulting in increased tenderness.

Evidence of proteolysis can be shown to occur among the sarcoplasmic proteins. The cathepsins, held within the lysosomes in vivo, were the proteolytic enzymes which were involved (Sharp 1963). As the cell lost integrity post-mortem the lysosomes ruptured and released the cathepsins (Tappel 1966). Sharp (1963) also demonstrated that proteolytic enzymes operated much more rapidly at 37°C than at 5°C, and equal tenderness in a shorter time were two advantages of aging at higher temperatures.

Quality Characteristics of Muscle and Their Measures

Tenderness

Tenderness is one of the most important quality characteristics of meat, but it is difficult to find an objective measure that correlates highly with the subjective evaluation of tenderness. The Warner-Bratzler shear apparatus is one of the most practical instruments available to the meat researcher for use as a tenderness estimator. Thirty-six animals were used by Cover and Smith (1956) to evaluate tenderness and the relationship between shear force and taste panel evaluations. They calculated correlation coefficients of 0.73 - 0.89 for shear force versus taste panel results. Ramsbottom and Strandine (1948) found a similar relationship (correlation coefficient 0.90). Hay et al. (1953) were able

to detect significant differences in tenderized (enzyme) beef cooked by four methods, with both the Warner-Bratzler shear machine and taste panel scores. However, Deatherage and Garnatz (1952) reported that no significant relationship existed between shear force and taste panel results; therefore, the synomymous use of the terms shear force (as determined by the Warner-Bratzler shear machine) and tenderness should be avoided. In later work by Machlik and Draudt (1963) it was found that when large numbers of values were to be taken on tenderness, the Warner-Bratzler shear machine could be used instead of a sensory panel.

To obtain reliable results with the Warner-Bratzler shear machine all samples must be evaluated at the same temperature (Machlik and Draudt 1963), and the sample size should be uniform as discussed by Kastner and Henrickson (1969).

The severity of rigor mortis affects product tenderness. Bendall and Davey (1957) described rigor mortis as the shortening of the sarcomere. In order to evaluate the extent of rigor mortis, T-I Ma et al. (1971) measured the sarcomere length as the average distance between "Z" lines on 15 myofibrils for each sample.

Juiciness

Juiciness of the finished product (raw) can be altered due to evaporation, protein denaturation, and pH as the proteins approach their iso-electric points (Lawrie 1966d). If the product was packaged, surface desiccation was reduced (Ingram 1962), but this encouraged bacterial growth. Meat with cut surfaces packaged under tension will tend to exude more moisture than the same product packaged loosely. Juiciness can be evaluated (Cagle 1969) by the pressed fluid method which was im-

plemented by the Carver Press. The meat sample (500 mg.) was pressed on filter paper at 10,000 pounds pressure for one minute and the resulting moisture ring was measured for total area, which can be correlated to product juiciness. Carr (1970) reported a similar procedure for determining pressed fluids. A 300 mg. ± 20 mg. sample was pressed at 10,000 pounds pressure for five minutes and the resulting fluid and meat rings were used to calculate the pressed fluids as a percent of the total water content. A similar method was used by Urbin et al. (1962) in order to evaluate the water binding properties of meat. A 500 mg. sample was placed on filter paper of standardized moisture content and pressed at 500 pounds per square inch for one minute. Sayre et al. (1963) expressed the resulting moisture ring as a ratio of the meat ring so as to measure "watery" conditions of the muscle or a decrease in muscle water-binding capacity.

Color

The color of meat products is primarily attributed to myoglobin even though in the live animal myoglobin accounts for only 10 percent of the total iron. Upon bleeding, most of the hemoglobin is removed and in the well bled animal 95 percent of the remaining iron is due to myoglobin. In the presence of oxygen, myoglobin is converted to two different pigments, oxymyoglobin and metmyoglobin. Oxymyoglobin is the oxygenated form while metmyoglobin is the oxidized form. Metmyoglobin formation is favored at low oxygen pressure while oxygenation of myoglobin occurs at normal oxygen pressures of the air. At all oxygen pressures myoglobin is constantly converted to metmyoglobin, but enzymatic oxidation of available substrates, glucose in particular, gives reducing

coenzymes which reduce metmyoglobin back to myoglobin. When there is a plentiful supply of reducing substances and oxygen, there are large amounts of oxymyoglobin (bright red) on the surface of the meat. As long as the supply of oxidizable substrates is present, the heme pigment remains in the reduced state, but when it is depleted the reducing power of the muscle is lost and metmyoglobin predominates (A.M.I.F. 1960a).

A.M.I.F. (1960b) reported that fresh meat placed in oxygen impermeable and moisture impermeable film under vacuum kept a long time; however, the purplish red color of reduced myoglobin is not acceptable to the retail consumer. In order to insure the desirable oxymyoglobin (bright red) color the partial pressure of oxygen in the environment must be high. In packaged products, if one desires a bright red surface an oxygen permeable wrap must be used. Temperature is also important to color development. Oxygen is solubilized by the surface fluids of the meat, then the meat takes up the oxygen from the fluid by diffusion. As the temperature decreases oxygen solubility in the water increases; therefore, meat should be allowed to develop color in a cool place.

Discoloration to form metmyoglobin can be enhanced by increasing temperature, bacterial growth, enzymatic action, or autoxidation (A.M.I.F. 1960b). Another important form of discoloration was discussed by Landrock and Wallace (1955). The lack of oxygen in packaged products gave reduced myoglobin which could be thought of as a form of discoloration even though it might be oxygenated to oxymyoglobin.

Several methods of evaluating the desirability of meat color have been investigated, and the tristimulus colorimetry method is one that is used today (Henrickson et al. 1956). Product color characteristics (hue, chroma, and value) can be evaluated by using the reflectance read-

ings from the Photovolt Reflection Meter (with tristimulus filters). The reflectance readings are then related to the International Commission on Illumination (ICI) standards which in turn are interpreted in terms of the Munsell Color System (Hunter 1942, Livingston 1959, and Nickerson 1958). The color dimensions (hue, chroma, and value) give objective values with which to discern color differences.

Flavor

Meat flavor has been studied for many years, but there is still much work needed. Several groups of compounds and their interaction have been investigated, but the source of meat flavor has not been narrowed to any one particular group of compounds.

Bases, Nucleotides, and Nucleosides. Spinelli et al. (1964), Jones et al. (1964), and Spinelli (1965) found that inosine monophosphate (IMP) degraded to hypoxanthine upon prolonged storage; therefore, hypoxanthine concentration and its "bitter" flavor could be used as an index of freshness. Even though IMP was degraded to hypoxanthine, Macy et al. (1970a) and Macy et al. (1970b) demonstrated IMP to be a desirable flavor precursor. Kuninaka et al. (1964) found that of the 2', 3', and 5' adenosine monophosphates only 5' AMP was "flavorful". However, most of the ribonucleotides exerted a major influence on the flavor of fresh foods (Khan et al. 1968).

Amino Acids and Carbohydrates. The reaction produced by heating amino acids with carbohydrates gives a "meaty" flavor and aroma that has been observed by several workers (Herz and Shallenberger 1960, Batzer et al. 1962, Wood 1961, Batzer et al. 1960, Macy et al. 1964a, and Macy

et al. 1964b).

Carbonyls and Related Compounds. Hornstein and Crowe (1963) and Hornstein and Crowe (1960) found that beef, pork, and lamb had basically the same water-soluble flavor precursors, and the differences in flavor could be attributed to the compounds found in the fat. Carbonyl compounds derived from the fat during heating may be involved in flavor and/or odor of the cooked meat product (Gaddis et al. 1959, Gaddis et al. 1960, Berry and McKerrigan 1958, and Bender and Ballance 1961).

Taste Panel. Quality aspects of meat, as determined by taste panel evaluation, are often used as research tools, but rigid guidelines and rules must be followed in order that meaningful results might be obtained.

Several different types of taste panel organization have been investigated, but the triangle test is one that is frequently used. The triangle test (Gridgeman, 1963) can be used when:

1. It is important when a simple measure is desired to determine a difference, and only a difference, among products.
2. It is difficult to define the essence of the difference objectively and unambiguously.

However, the same author (1970) observed the paired comparison to be better than the triangle test when evaluating "marginal" sensory differences, and Byer and Abrams (1953) noted that the two-sample test resulted in discrimination of higher statistical significance than did those of the triangular test.

Even though the triangle test has been criticized under certain conditions, when it came to evaluating product differences it was found

to be statistically more efficient than the paired comparison and gave equal or superior results (Dawson et al. 1963a). Dawson et al. (1963a) also used the triangle test for quality control and for product development and improvement when the products approached complete homogeneity within lots. The advantages were that small differences between samples could be determined and direct comparison of the sample required only a short memory.

Taste panel evaluations depend on physical conditions of the panel member or on the environment. Many of these conditions might affect flavor acceptance and preference tests. Therefore, preparation prior to taste panel evaluation is very important.

Dawson et al. (1963b) found a panel of 3-10 members of sufficient size, depending upon experimental unit variability and the magnitude of differences among samples. They also observed individual factors such as health, age, sex, smoking, and emotional factors that could cause taste variability; therefore, individual sensitivity varied from time to time. All sensory thresholds decreased with age.

Berry and Ziegler (1969), Lees (1968), Dawson et al. (1963a), and Kramer and Twigg (1966) all formulated, in part, the following precautions and guidelines for conducting sensory panels. Panelists should be selected on the basis of their sensitivity to various organoleptic parameters (ability to discern bitter, salty, sour, and sweet). The environment should be free from distractions: odor free, air conditioned, noise free, and the colors should not distract the panelists. Use white light that is uniform and adjustable when the color needs to be masked. Separate booths to insure individual responses. Clear, concise instructions should be given to each panel member and nothing should be said

that would indicate the desired results or anticipated outcome. Samples should be served in a uniform manner with respect to all factors other than the factor to be evaluated. Presentation of the samples should not always be done in the same sequence as the results may be biased. The number of samples per sitting is dependent upon the blandness of the food. More samples can be tasted at one time if they are bland. Simple, easily understood recording forms should be used to facilitate panel understanding and ultimate data evaluation.

The triangle test warrants precautions that are peculiar to its success as a research tool. When the odd sample was held constant and the other two samples were duplicates this improved the ability to detect differences, but panel members tended to select the middle sample as the odd sample (Dawson et al. 1963a).

"Hot" Processing

"Hot" processing and its application to pork carcasses has received considerable attention, but only limited research has been accomplished with the bovine carcass.

Pork muscle processed pre-rigor had a greater emulsifying capacity and more salt-soluble proteins than post-rigor muscle (Trautman 1964). Johnson (1969b) found a significant difference in salt-soluble proteins between pre- and post-rigor treated porcine muscle.

Pulliam and Kelly (1965) "hot" processed porcine hams and found higher bacterial counts than in the conventionally processed hams when evaluated prior to smoking, but bacterial counts were low in both groups after smoking. However, Barbe et al. (1966) and Barbe and Henrickson (1967) found less total contamination on "hot" processed ham, and it was

extrapolated that the more rapidly processing was completed after death the less opportunity existed for undesirable bacterial growth to occur.

When yield, tenderness, juiciness, moisture content, and flavor of "hot" processed hams, cured and smoked prior to chilling, were compared to the conventional process, the "hot" processed product proved to be of equal or superior quality (Mandigo and Henrickson 1966). Ham muscle excised hot, cured, and canned exhibited less free fluids in the can, more total moisture, greater shear values, more nitrosopigments, and greater cure diffusion than "cold" processed ham muscle (Reddy and Henrickson 1969). Arganosa and Henrickson (1969) found more total pigments and myoglobin in pre-chill versus post-chill processed porcine muscles. Stability of cured meat pigments of pre-chill cured pork was comparable or superior to the same product cured after chilling (Parr 1966).

Freshly cut "hot" porcine muscle was darker than its chilled counterpart, but after chilling no difference could be detected. Henrickson (1968) also noted that the grey fat of the freshly slaughtered pork carcass turned white when chilled on a smooth surface. The same author (1968) evaluated the tenderness of the "hot" processed pork product using the Warner-Bratzler shear machine and percent rigor mortis, but he found no evidence discriminating against "hot" processing. Bovine muscle, on the other hand, exhibited a decrease in tenderness in the Semitendinosus muscle processed pre-rigor, but the Gluteus medius and Longissimus dorsi muscles did not increase or decrease in tenderness due to treatment (Reddy 1962). Beef lean, as did pork, showed a greater emulsifying capacity for pre-rigor processing than the same characteristic measured on post-rigor beef chuck (Acton and Saffle 1969).

Cagle (1969) noted that slicing pre-rigor pork muscle decreased tenderness. It is interesting that the same author observed decreased tenderness associated with the pork Longissimus dorsi muscle of the carcass side attached to the leg used for suspension during bleeding.

CHAPTER III

MATERIALS AND METHODS

Two Hour Holding Period

Six Hereford steers of approximately the same weight and market grade (Choice grade) were used. The animals were delivered to the Meat Science Abattoir 24 hours before slaughter. After a 24 hour shrinkage period, the steers were weighed and then Federally inspected (ante-mortem). Live weights of the animals ranged from 880 to 1022 pounds. Ante-mortem treatment and management of each animal were noted as these could influence post-mortem metabolic reactions and ultimate product quality. Each animal was then rendered unconscious with a Cash Percussion Stunner, raised from the floor by both legs and bled in the conventional manner. The time of death was recorded. Skinning and evisceration were accomplished as quickly as possible, within 45 minutes after death. Care was exercised to insure proper splitting of the carcass. Federal Inspection (post-mortem) was given to the washed, split carcass and a hot weight recorded for both the left and right sides. Either the right or left side of the carcass was assigned to one of two treatments; removing the muscles while the carcass was still warm ("hot" boning) or removing the muscles after a 48 hour holding period ("cold" boning).

Muscle Excision - "Hot" Boning

The side used for the "hot" boning treatment was then prepared for dissection into individual muscles and muscle systems. The chuck, shank, and brisket were removed as an intact piece, weighed, and used only for calculating yield. This forequarter part was removed between the fifth and sixth ribs, the usual division for the wholesale chuck (Figure 1). The primary reason for not using the chuck, shank, and brisket for data other than yield was that it would have been extremely time consuming to excise the muscles of the forequarter. The author felt that the remainder of the carcass would give reliable results for the other parameters under investigation. Both sides, while suspended from the rail, were maintained at room temperature (24°C) until the muscles were removed from the "hot" boned side (minus chuck, shank, and brisket). Upon removal of the intact muscles, muscle systems, fat trim, and lean trim from the suspended skeleton, each of the components including the skeleton was placed in separate Cry-O-Vac bags (S-507) to prevent moisture evaporation. Most of the fat cover on the excised muscles was removed down to the epimysial connective tissue. The muscles and muscle systems dissected as intact units were: Biceps femoris, Semimembranosus and Adductor, Semitendinosus, Quadriceps (Vastus intermedius, Vastus lateralis, Vastus medialis, and Rectus femoris), Gluteus "complex" (Gluteus medius, Gluteus accessorius, and Gluteus profundus), Longissimus dorsi (posterior of the fifth rib), and the Psoas major. The remaining muscles were put into lean trim once the majority of the fat had been removed. Carcass dissection was completed at approximately two hours post-mortem.

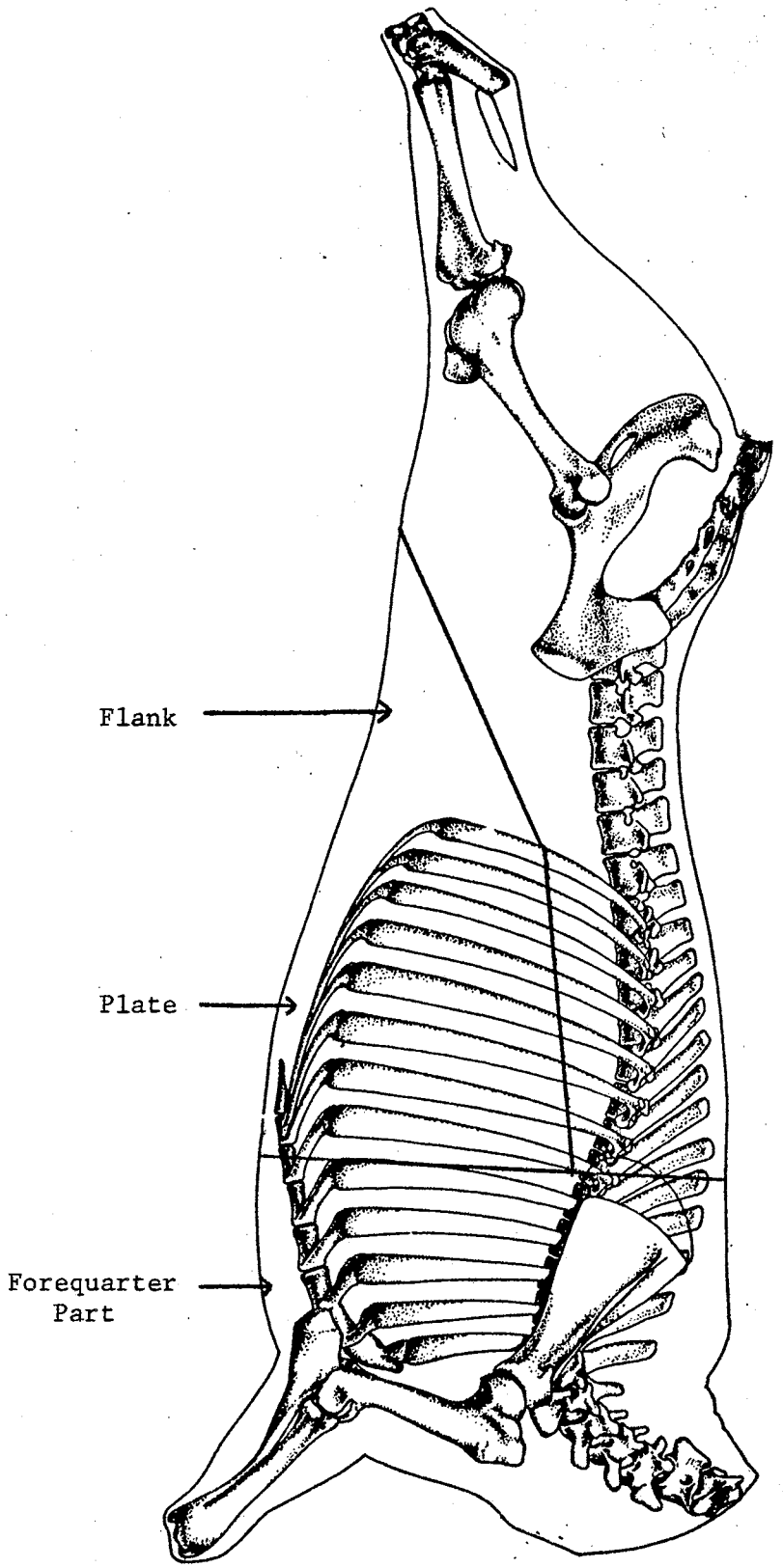


Figure 1. Diagram of Carcass Preparation for Hot and Cold Boning

pH Determination

The pH determinations were used as an index of the extent and rate of post-mortem glycolysis in excised muscles.

After the last muscle had been removed from the skeleton a muscle sample was extracted from the excised Psoas major ("hot" boned) and from the attached Psoas major ("cold" boned). A 10 gram sample of finely diced lean from each Psoas muscle was placed in 50 milliliters of distilled water and the pH was recorded, using a glass electrode, along with the corresponding time. The time lapse from exsanguination to the initial pH reading varied from two to three hours. The integrity of the other test muscles was not disturbed. Muscle integrity and the resulting tension on the skeleton influence product tenderness; thus, this was the reason for using only one muscle for pH determinations. The intact "cold" boned side and the excised packaged parts of the "hot" boned side were then placed in a $2^{o}C$ cooler until 48 hours after exsanguination. Psoas major muscle samples for pH determination were removed each hour for five hours after the first determination and then 24, 47, and 48 hours from the time of death. The author attempted to obtain freshly cut transverse sections from the same general area using the skeleton as a guide on both the right and left Psoas major muscles. This was done in order to control variation between muscles due to possible variation in pH along the muscle.

Muscle Excision - "Cold" Boning

After the 46 hour cooling period at $2^{o}C$, the "cold" boned side was broken down into the forequarter part (chuck, shank, brisket), fat trim, lean trim, and the muscles and muscle systems corresponding to those

previously "hot" boned. Muscle excision was accomplished as the carcass (minus chuck, shank, and brisket) was suspended from the rail. Consequently, the method of dissection for the "cold" side was the same as for the "hot" boned side.

Yield

After the "cold" boned side had been fabricated, each individual component (forequarter part, muscles, muscle systems, fat trim, lean trim, and bone) was weighed to the nearest tenth of a pound and the weights were recorded. The packaged component parts from the "hot" side were taken from the Cry-O-Vac bags and weighed. By totaling the weight of the parts from the sides and dividing by the appropriate side weight, percent loss was calculated. The formula for calculating percent loss is:

$$\frac{\text{Hot Side Weight - Sum of Side Components}}{\text{Hot Side Weight}} \times 100 = \text{Percent Loss}$$

The Psoas major muscle taken from the "hot" boned side was weighed before sampling for pH determinations and this value was recorded for both the right and left sides. Therefore, the Psoas major weight for both treatments was the same in each individual animal.

Sampling for Color, Pressed Fluid, Percent Moisture, Percent Fat, Histological Examination, Organoleptic Evaluation, Percent Cooking Loss, Shear Force, and Chemical Determinations

After the yield had been determined, four muscles were selected for quality evaluation by both subjective and objective measures. The Biceps femoris (B.F.), Semitendinosus (S.T.), Semimembranosus (S.M.), and Longissimus dorsi (L.D.) were selected as the test muscles. From a

practical point of view all muscles of the carcass could not be evaluated; therefore, these specific muscles were utilized because they represented much of the carcass weight and value. Also within this group of selected muscles there was much variation in tenderness. While these muscles were held at 2°C, steaks were cut from them to compare both the "hot" and "cold" boned treatments. The selected muscles were fabricated into steaks for detailed quality evaluation.

Two samples for each determination, excluding the histological samples, were cut from each test muscle (Figure 2). Steaks for the organoleptic evaluation, percent cooking loss, shear force, and chemical determinations were packaged, labeled, and frozen (-84°C) for analysis at a later date. The steaks for histological examination, color value, pressed fluid, percent moisture, and percent fat determinations were held fresh at 2°C until sampled or analyzed.

Objective Color Difference Determinations

Sixteen steaks (two steaks from four muscles from both the right and left sides of the carcass) were evaluated on the basis of color value. The steaks were permitted to oxygenate at 2°C for one hour before determinations were taken. A Photovolt Reflection Meter (model 610) with a 610-Y search unit was used to measure the percent reflectance from the cut surface of the steaks. The Reflection Meter, with a green filter in the search unit, was adjusted to 100 percent reflectance using a magnesium oxide surface. A Munsell 5R 5/12 chip was then used as a standard. Other standards could have been used, but the one selected was approximately the color of the freshly cut oxygenated beef samples.

POSTERIOR END OR MUSCLE INSERTION

CHEMICAL DETERMINATIONS
ORGANOLEPTIC EVALUATION AND PERCENT COOKING LOSS STEAK 2 - 2.54 CENTIMETERS
PRESSED FLUID PERCENT MOISTURE PERCENT FAT STEAK 2 - 2.54 CENTIMETERS
SHEAR FORCE STEAK 2 - 5.08 CENTIMETERS
COLOR HISTOLOGICAL EXAMINATION STEAK 2 - 2.54 CENTIMETERS
MIDLINE OF THE MUSCLE
ORGANOLEPTIC EVALUATION AND PERCENT COOKING LOSS STEAK 1 - 2.54 CENTIMETERS
PRESSED FLUID PERCENT MOISTURE PERCENT FAT STEAK 1 - 2.54 CENTIMETERS
SHEAR FORCE STEAK 1 - 5.08 CENTIMETERS
COLOR STEAK 1 - 2.54 CENTIMETERS
CHEMICAL DETERMINATIONS

ANTERIOR END OR MUSCLE ORIGIN

Figure 2. Schedule for Removing Steaks for Various Quality Determinations on Each Test Muscle

Hue, value, and chroma are the dimensions of color: hue being the color (red, purple, etc.), value which is the degree of lightness to darkness (white = 10, black = 0), and chroma the intensity of a particular color (light red, medium red, etc.).

Only the value dimension was collected for the test steaks by using the green filter in the Photovolt search unit. The reflectance readings were then converted to Munsell value scores (Nickerson 1958). Thus, the degree of lightness and darkness was determined and used to express color differences. No attempt was made to determine the actual meat color. While collecting reflectance values the author avoided coarse marbling as this would influence the ultimate reflectance scores. Samples for histological examination were extracted from the steaks used for color differences (Figure 2), and these samples were stored in 10 percent buffered formalin until they were utilized. Two 1.27 centimeter cores were taken from each steak used for the histological examination.

Pressed Fluid

Sixteen steaks (two steaks per four muscles for the two boning techniques) were used for the determination of pressed fluid. Three cores (1.27 centimeters in diameter) were cut from each steak, and a transverse section of approximately 300 milligrams was extracted from the center of each core. The muscle tissue section was then placed on Whatman No. 1 qualitative filter paper that was 18.5 centimeters in diameter. The filter paper and sample were placed between two clean plexiglass plates and pressed five minutes at 5000 pounds load on the ram of a Carver Laboratory Press. Care was exercised to avoid moisture evaporation from the samples prior to pressing. Prior to use, the filter

paper was held in a desiccator jar which contained a small amount of saturated potassium chloride. This insured that the filter paper was of a constant humidity (Carr 1970). Once the samples were pressed, the resulting meat ring was traced with a pencil and the pressed sample was discarded. The filter papers containing the traced meat ring and the moisture ring were dried for 24 hours at room temperature. After the papers were sufficiently dry, each area (meat ring and moisture ring area) was measured twice using a Compensating Polar Planimeter. Therefore, each area was the result of averaging two readings. The measured areas were used to calculate a dimensionless ratio which represented the pressed fluid in that sample (Sayre et al. 1963).

$$\frac{\text{Moisture Ring Area}}{\text{Meat Ring Area}} = \text{Ratio}$$

Thus, the larger the ratio, the more pressed fluid per unit area of sample.

The steaks used for pressed fluid sampling were immediately trimmed of excess residual exterior fat, ground and blended to a paste consistency for percent moisture and percent fat analysis. The rheostat controlled Sorvall Omni-Mixer cannister was placed in an ice water bath to prevent the sample from overheating during blending. The blended samples were placed in labeled jars and refrigerated ($2^{\circ}C$) until the next day.

Percent Moisture

Duplicate determinations were made on each blended sample; therefore, 32 moisture determinations were conducted on each carcass. Approximately a two gram sample was weighed into a dry, tared aluminum

planchet. The sample was spread into a thin layer to insure thorough drying, and it was dried for 24 hours at 110°C. The dried planchet and sample were cooled to room temperature in a desiccator jar and reweighed. The formula for calculating percent moisture is:

$$\frac{\text{Sample Weight - Dry Sample Weight}}{\text{Sample Weight}} \times 100 = \text{Percent Moisture}$$

Percent Fat

The L.D. muscle was used as a representative muscle; therefore, eight samples were analyzed for crude fat percentage found in each carcass. Approximately a four gram sample was weighed into a dry, tared fat thimble which was plugged with non-absorbent cotton. Cotton was also placed on top of the sample after weighing. A dried ether extraction beaker was also weighed for each sample. The thimble containing the wet sample was dried for 24 hours at 110°C, cooled in a desiccator, and then placed on the ether extraction apparatus (Goldfisch) along with the companion beaker. Each sample was extracted for at least 21 hours. After extraction, the excess ether was collected by vaporization and condensation and the beaker containing the fat was dried for 30 minutes at 110°C to completely remove all the ether. The beaker and fat were cooled in a desiccator and reweighed. The formula for calculating percent fat is:

$$\frac{\text{Fat Weight}}{\text{Sample Weight}} \times 100 = \text{Percent Fat}$$

Shear Force

The frozen steaks held for shear force determinations were thawed

at 2°C for 24 hours. Two steaks from each of the four test muscles were evaluated for both "hot" and "cold" boning; therefore, 16 steaks were analyzed from each carcass. The thawed steaks were labeled and cooked in deep fat at 135°C until an internal temperature of 72°C was reached. This provided a firm, dry, well cooked product (Kastner and Henrickson 1969). The cooked steaks were chilled for 24 hours at 2°C in order to provide additional firmness that insured uniform cores. A mechanical boring device was also used to extract the meat cores because it aided in providing core uniformity (Kastner and Henrickson 1969). Three 2.54 centimeter diameter cores were taken at random from each steak and each core was sheared three times by the Warner-Bratzler shear apparatus. This resulted in nine shears per steak. The three shear values from each core were summed and averaged, then the resulting averages of the three cores were pooled and averaged to obtain a shear value for the entire steak. If a shear force exceeded 50 pounds the maximum reading of 50 was recorded because the shear machine had a capacity of only 50 pounds.

Organoleptic Evaluation

Even though all four test muscles were sampled for taste and color, only the L.D. muscle was appraised by the panel. Steaks 1 and 2 (Figure 2) from the L.D. muscles of both the right and left sides of the carcass were thawed for 24 hours at 2°C. Seven untrained panel members were used for each trial, although all seven members were not the same from trial to trial. The judges consisted of both men and women of different ages selected from the employees of the Meat Science Laboratory.

The triangle test was used to determine whether differences in raw

color or cooked flavor existed between "hot" and "cold" boning. Steak 2, assigned to the taste and color panel (Figure 2), from the left and right sides of the carcass was sampled for visual appraisal of color differences. Two samples, 3.81 centimeters x 5.08 centimeters, were taken from either the "hot" or "cold" boned L.D. muscle (steak 2) and one sample, the same size, was taken from the remaining steak 2. This resulted in three raw samples, two of which were from one boning process and one sample from the other. These samples were allowed to oxygenate at 2°C for one hour prior to visual appraisal. The panel members working individually, were asked to select the odd sample on the basis of raw color differences. The modified combination flavor, color evaluation sheet is shown in Figure 3 (Kramer and Twigg 1966).

The remaining portion of steak 2 and steak 1 (intact) from both the "hot" and "cold" boned L.D. muscles were blotted, weighed, and labeled before cooking. The steaks, with thermometers inserted, were cooked in an oven at 163°C until an internal temperature of 66°C was reached. After cooking, the steaks were blotted, reweighed, and prepared for sample extraction for the taste panel analysis. Each panel member received three cores (1.90 centimeters in diameter) for evaluation according to the modified flavor, color score sheet (Figure 3). Two of the cores were from one boning process and one core from the other. During the conduction of the taste panel, the light source was limited to reduce bias due to cooked color differences.

Percent Cooking Loss

Pre- and post-cooked weights were taken on the four L.D. steaks used for the taste panel (mentioned above). The percent cooking loss differ-

Date _____ Product _____

Project _____ Animal No. _____

Name of Judge _____

Separate for Flavor Only

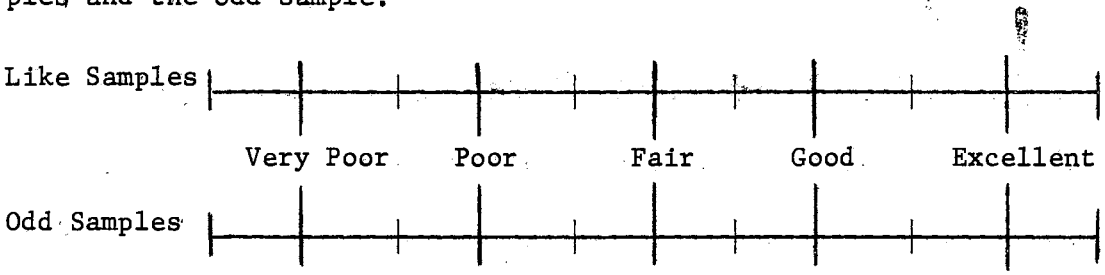
Sample	Check Like Samples	Flavor Difference Between Odd and Like Samples	Did you Check By Guess?
(1)	(2)	(3)	(4)
_____	_____		
_____	_____	____ None ____ Slight	Yes _____
_____	_____	____ Moderate ____ Much	No _____

Check by guess if no difference is detectable.

5. If you checked a Moderate or Much in the flavor difference column (No. 3), then indicate below whether you consider either the odd sample or like samples to have an undesirable flavor.

   Odd Sample: Yes _____ No _____ Like Samples: Yes ____ No _____

6. Rate for Flavor Only. Place a check mark above either a short or long line on the scale below to indicate how you rate the like samples and the odd sample.



7. (a) Did you detect any kind of difference, other than flavor, between the samples? Yes _____ No _____

   (b) If "Yes", what kind of difference? _____

Separate for Color Only

Sample	Check Like Samples
(8)	(9)
_____	_____
_____	_____
_____	_____

10. Comments concerning color: _____

Figure 3. Flavor and Color Evaluation Sheet

ence between "hot" and "cold" boning was thus compared. The formula for calculating percent cooking loss is:

$$\frac{\text{Raw Steak Weight - Cooked Steak Weight}}{\text{Raw Steak Weight}} \times 100 = \text{Percent Cooking Loss}$$

Chemical Determinations

The samples that were taken for chemical analysis (Figure 2) were not to be analyzed unless flavor differences were discovered. No differences in cooked flavor were detected; therefore, these samples were not utilized.

Histological Examination

Histological samples were taken, but time did not permit sufficient data to be collected in this area; so, the results were not reported.

Statistical Analysis

The Analysis of Variance in conjunction with the F-test was used to analyze differences in percent loss (yield), objective color measurements, percent moisture, percent fat, pressed fluid, shear force, and percent cooking loss.

The method for determining statistical significance for flavor and color differences, as evaluated by the taste and color panel, is given in Fundamentals of Quality Control for the Food Industry (Kramer and Twigg 1966).

A flow chart that indicates treatment sequence and assignment is shown in Figure 4.

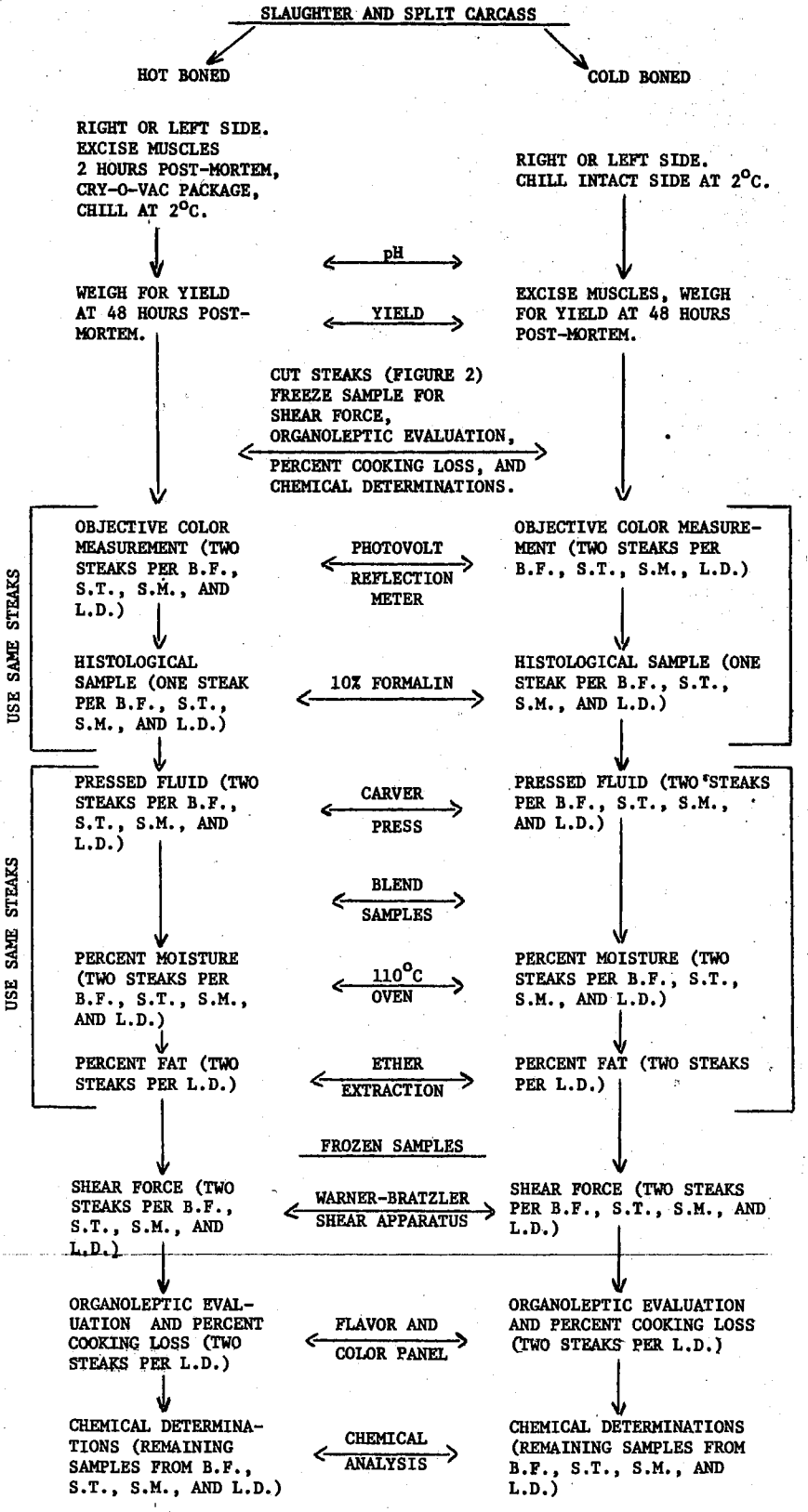


Figure 4. Treatment Sequence and Assignment for the Two Hour Holding Period

Five Hour Holding Period

As it was determined that tenderness was a problem area, the author decided to extend the holding period on the skeleton before excising the "hot" boned muscles. Only the variations in the original materials and methods (two hour holding period) will be discussed in this section. Basically the methodology was the same, but there were a few alterations. Six (Good grade) Hereford steers ranging from 952 to 1082 pounds were used.

The "hot" boned side was held five hours at 16°C prior to muscle excision. The holding time was extended to decrease shear force differences between "hot" and "cold" boning and a 16°C holding temperature was incorporated to insure a constant ambient atmosphere. A recording Honeywell Potentiometer was utilized to keep a record of temperature change in the 16°C cooler. As muscles pass through rigor mortis, it is best to hold them at 16°C. The advantages of this temperature have been cited by several authors (Locker and Hagyard 1963, Forrest et al. 1969, and Smith et al. 1969).

After post-mortem inspection the "cold" boned side was weighed and placed in a 2°C cooler and the "hot" boned side was removed to the 16°C ambient temperature. The pH determinations, from the Psoas major muscles, were begun approximately one hour post-mortem, and were continued on an hourly basis until five hours post-mortem. Both the "hot" boned and "cold" boned sides were sampled for pH evaluation. The "hot" boned side was then readied for muscle excision (after holding for five hours) by removing the chuck, shank, and brisket between the fifth and sixth ribs. Also the flank and plate were removed in the conventional manner because the muscles contained therein were not utilized in this

holding period (Figure 1). The resulting "streamlined" hindquarter was weighed and used as a basis for calculating yield. The "streamlined" hindquarter was placed back in the 16°C cooler for muscle excision. Upon muscle extraction, another pH reading was taken from the Psoas major muscles. The "hot" boned components from the "streamlined" hindquarter were packaged, as outlined for the two hour holding period, and were held at 2°C with the "cold" boned side until 48 hours post-mortem. A 48 hour pH reading was taken from the excised "hot" boned Psoas major and the intact "cold" boned Psoas major muscles. After the final pH readings were taken, the intact "cold" boned side was reweighed so as to evaluate yield in terms of percent loss. The "cold" boned side was prepared for muscle excision by fabricating it into a "streamlined" hindquarter. The prepared hindquarter was taken into the 16°C cooler during muscle excision. This insured a constant ambient temperature. Upon removing the "cold" boned muscles and muscle systems, percent loss was determined for both the "hot" and "cold" boned treatments. The formulas for percent loss are:

"Hot" Boned Side

$$\frac{A - B}{A} \times 100 = \text{Percent Loss}$$

A = Intact "Streamlined" Hindquarter Weight.

B = Sum of "Streamlined" Hindquarter Components.

"Cold" Boned Side

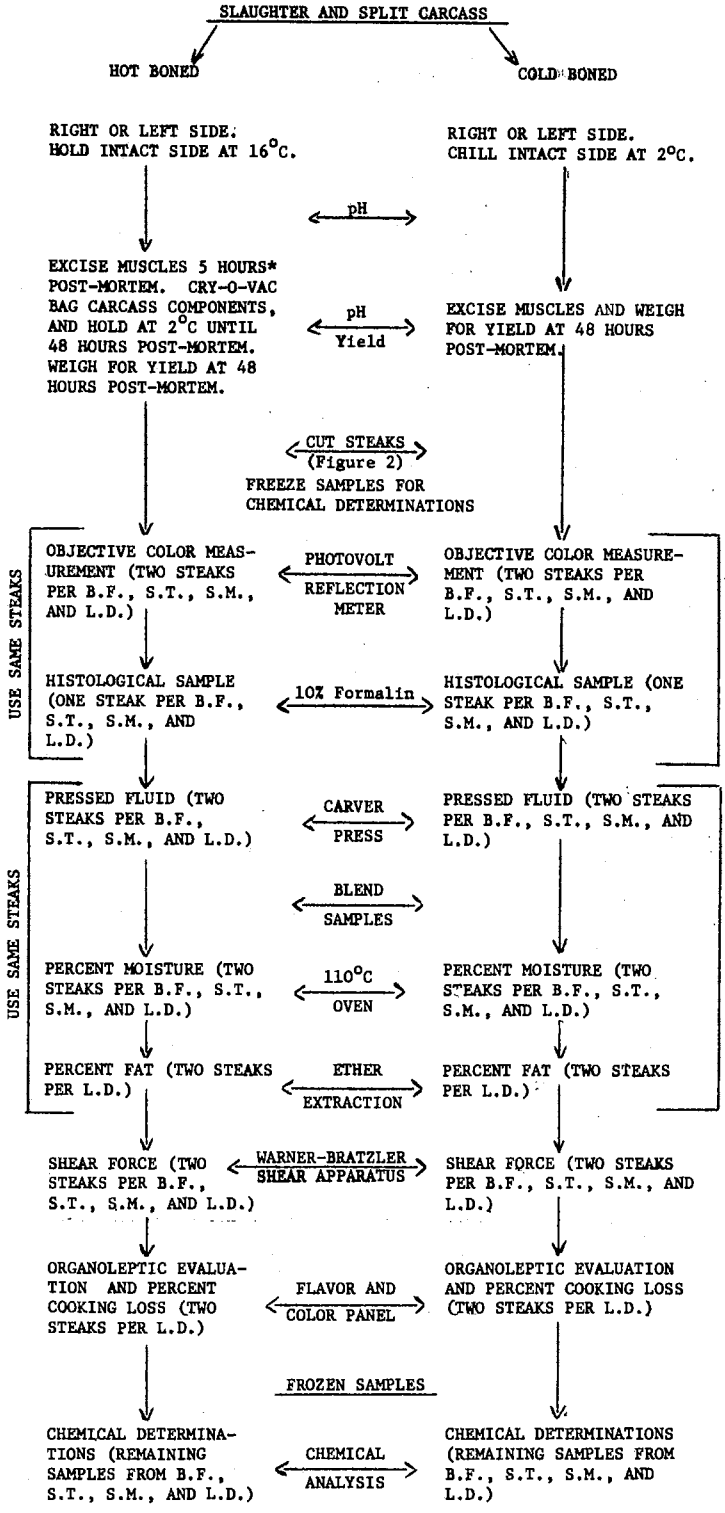
$$\frac{\text{Hot Side Weight} - \text{Shrunk Side Weight}}{\text{Hot Side Weight}} \times 100 = \text{Percent Loss}$$

Samples that were extracted from the Psoas major muscles were weighed and added back into the weights of these muscles.

Steaks were removed from the test muscles as outlined in the two hour holding period (Figure 2). However, all test steaks were held in an unfrozen condition at 2°C excluding those samples held for chemical determinations. The percent fat analysis was determined as outlined in the two hour holding period; however, the prepared samples were held in a frozen state until used. All other quality analyses were conducted as enumerated for the two hour holding period. The flow chart for the five hour holding period is given in Figure 5. The samples for shear force, organoleptic evaluation, and percent cooking loss were analyzed at approximately 72 hours post-mortem.

Eight Hour Holding Period

In order to decrease the difference in shear force between "hot" and "cold" boning, the author decided to further extend the holding time on the skeleton prior to excising the "hot" boned muscles. Six (Good grade) Hereford steers ranging from 820 to 925 pounds were used. The eight hour holding period was conducted exactly as the five hour holding period except that the side to be "hot" boned was held eight hours at 16°C prior to muscle excision. In addition, pH determinations were begun within one hour post-mortem and were continued on an hourly basis until five hours post-mortem. Two other readings were taken: one prior to fabrication of the "hot" boned side (eight hours post-mortem) and one immediately after the side components were removed from the skeleton. Before excising the muscles from the "cold" boned side at 48 hours post-slaughter, another pH reading was taken. The treatment sequence and



*Eight hours, for eight hour holding period

Figure 5. Treatment Sequence and Assignment for the Five and Eight Hour Holding Periods

assignment for this holding period is shown in Figure 5. Two animals were analyzed weekly whereas only one steer was studied weekly for the two and five hour holding periods.

CHAPTER IV

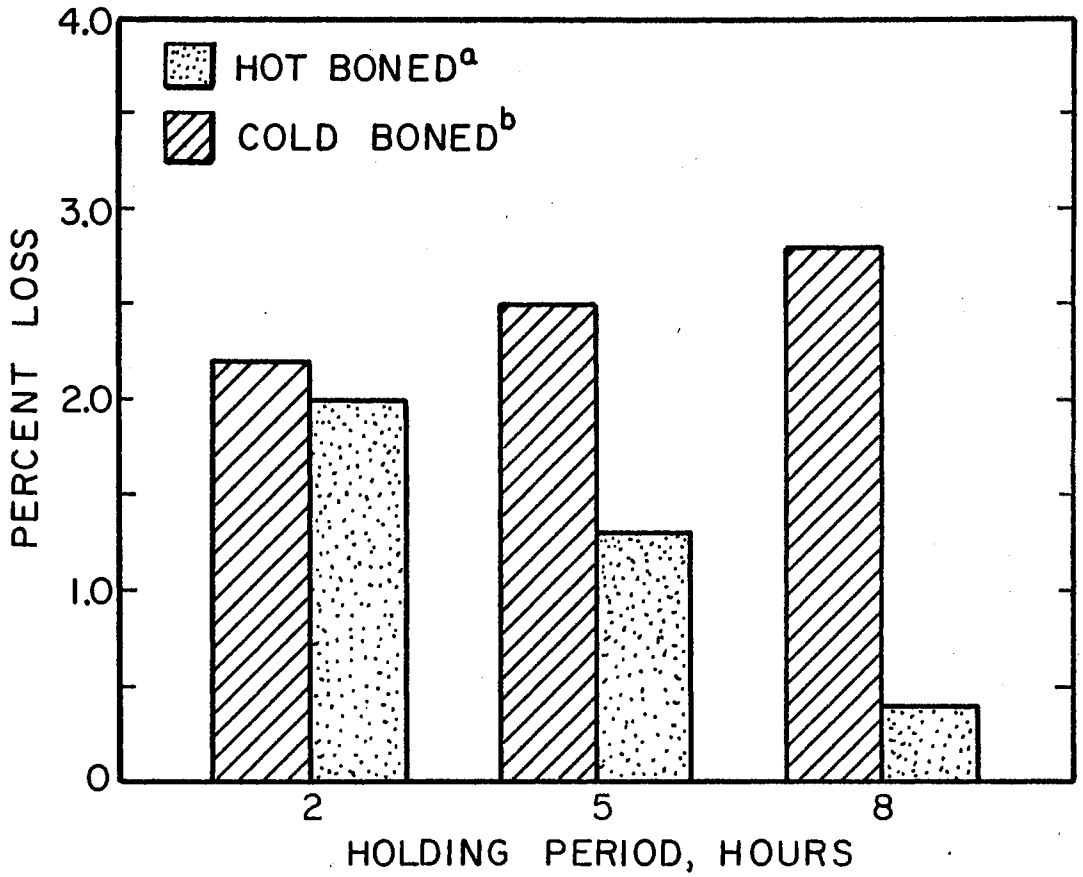
RESULTS AND DISCUSSION

Yield

Even though more extensive yield studies should be initiated, it appeared that "hot" boning increased yield when the product was treated as outlined in this study.

The difference between percent loss for "hot" and "cold" boning in the two hour holding period (Figure 6) was statistically non-significant ($P > .05$); however, in both the five and eight hour holding periods (Figure 6) significant differences ($P < .005$) existed between percent loss for "hot" and "cold" boning (Table III, Appendix).

For all holding periods the "hot" boned treatment had a smaller average percent loss than the control (Figure 6). One explanation for this was that the investigators' dissection technique improved with time. Thus, the time lapse between muscle excision and placing the muscles into Cry-O-Vac bags was reduced from the two to the eight hour holding period; consequently, this may account for part of the decrease in percent loss. Therefore, less time was available for surface desiccation of the muscles and muscle systems. Consequently, once a muscle is removed from its intact status it should be packaged immediately. The average shear force differential between "hot" and "cold" boning decreased with increased post-mortem holding time on the carcass (Figure 13, page 58); thus, muscle contraction decreased with holding time.



[a] Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b] Cold boned side held 48 hours post-mortem for all holding periods.

Figure 6. Percent Loss for Hot Versus Cold Boning for Three Holding Periods

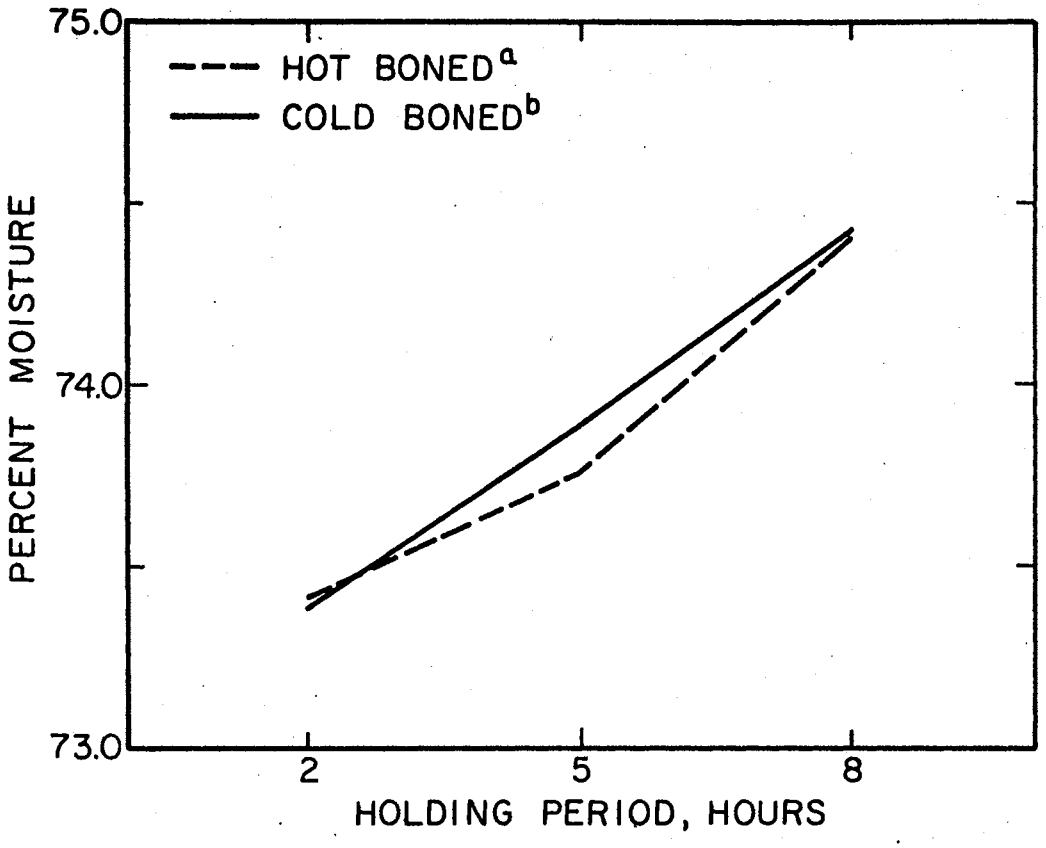
Therefore, the decrease in the severity of contraction might have accounted for the decreased percent loss for "hot" boning when all three holding periods were compared (Figure 6). This was especially true when a large cut surface was exposed because muscle contraction forced a physical release of moisture. An aid in decreasing percent loss or increasing yield would be to leave the epimysium intact whenever possible during muscle dissection. Increased percent loss for the control from the two hour to the eight hour holding periods (Figure 6) could have been due to decreased carcass quality; thus, less fat cover and more loss due to desiccation from the surface lean was indicated.

In the remainder of the results and discussion the following abbreviations will be used: S.M. (Semimembranosus), S.T. (Semitendinosus), B.F. (Biceps femoris), and L.D. (Longissimus dorsi).

Percent Moisture

For each holding period (two, five, and eight hours) there was a non-significant difference ($P > .05$) between "hot" boning and the control for percent moisture (Figure 7). The analysis of variance for percent moisture is shown in Table IV (Appendix). Therefore, there was no disadvantage to "hot" boning when percent moisture was considered.

There was a general increase in the percent moisture from the two hour holding period to the eight hour holding period (Figure 7). This apparent increase corresponded to the increase in percent loss (Figure 6) for the "cold" boned muscles. At first this may appear inconsistent, but if carcass quality decreased from the two hour holding period to the eight hour holding period then this would indicate less intramuscular fat and a resulting increase in moisture on a percentage basis. The



[a] Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b] Cold boned side held 48 hours post-mortem for all holding periods.

Figure 7. Percent Moisture for Hot Versus Cold Boning by Holding Periods

quality of the steers could have varied from one holding period to the next even though effort was made to keep the same grade steers from one holding period to the next.

As would be expected, moisture levels varied from muscle to muscle such that there was a significant difference in percent moisture among muscles in all holding periods ($P < .005$). These differences can be observed in Figure 8 and Table IV (Appendix). The boning x muscles interaction was non-significant ($P > .05$) for all holding periods; therefore, the relationship among the muscles was essentially the same for each boning process (Figure 8).

There were significant differences in percent moisture between steaks in the test muscles for all holding periods ($P < .005$). See Figure 9 and Table IV (Appendix). The boning x steaks in muscles interaction was non-significant ($P > .05$) for all holding periods; thus, the relative response for percent moisture between steaks 1 and 2 in the test muscles was basically the same for each boning process.

These data indicate that percent moisture within the muscles under investigation was not significantly influenced by "hot" boning. Therefore, one may conclude that the primary difference in yield (between "hot" and "cold" boning) as defined by percent loss was due to surface desiccation and not a loss of moisture from within the muscles. This emphasizes the desirability of packaging carcass components immediately upon removal from the skeleton.

Pressed Fluid Ratios

Even though pressed fluid ratios were statistically different for "hot" boning and the control, these differences were not detected organo-

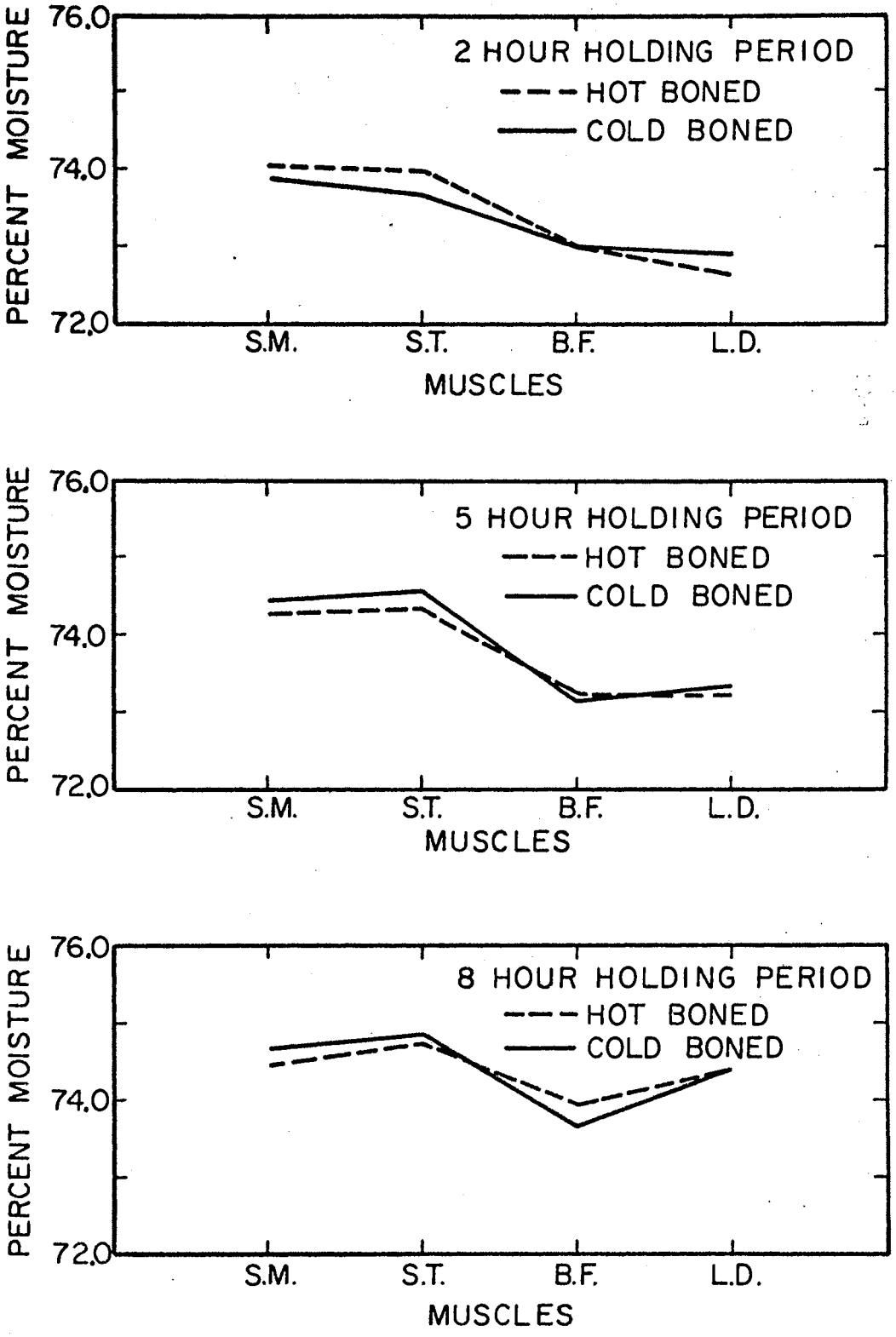


Figure 8. Percent Moisture for Four Muscles by Boning Process

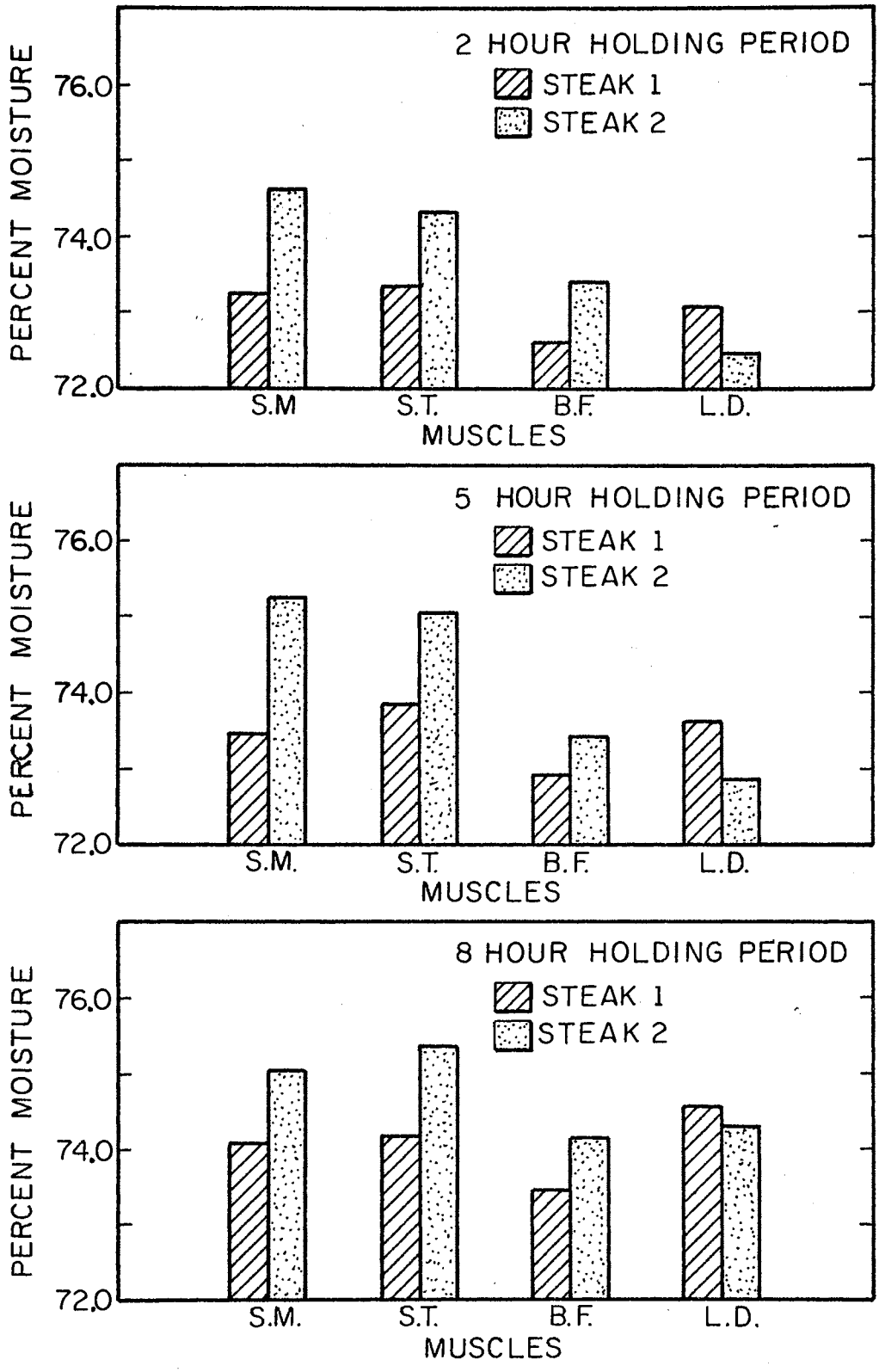


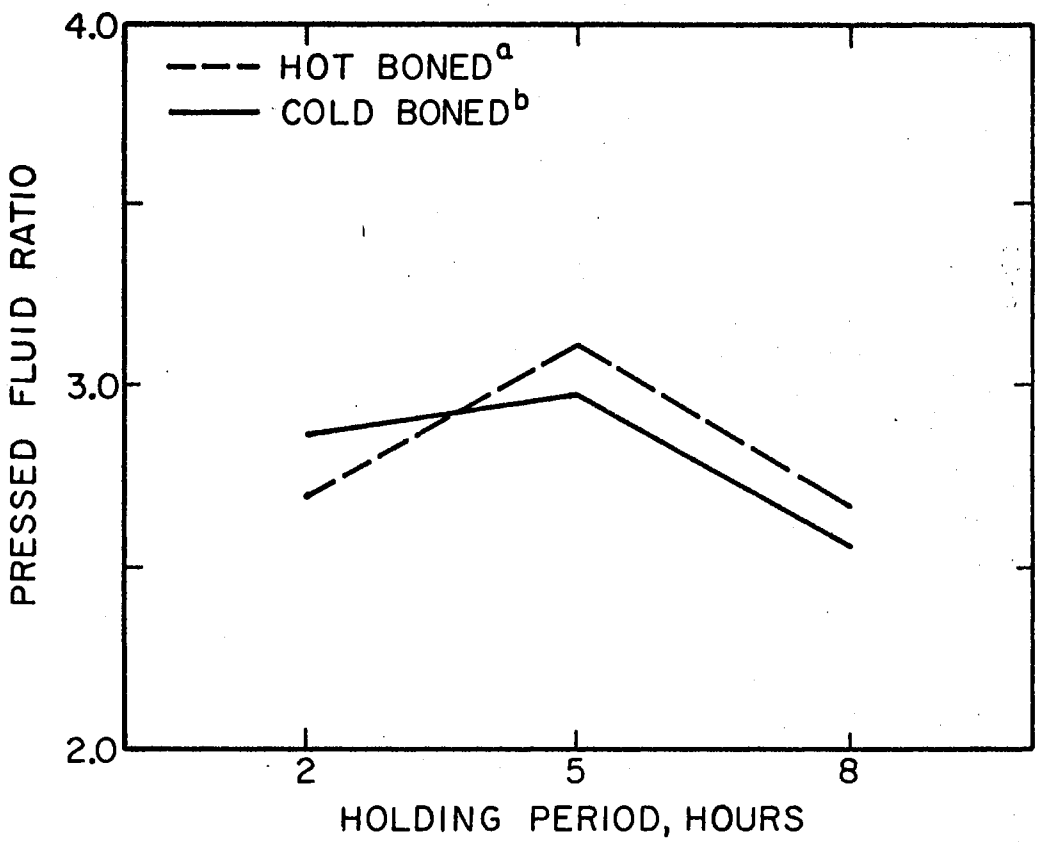
Figure 9. Percent Moisture for Two Steaks in Four Muscles

leptically (Table I, page 72). Thus, there was no detected effect of juiciness differences between "hot" and "cold" boning as it related to flavor of the cooked product.

An analysis indicated a significant ($P < .005$) holding period x boning interaction (Figure 10); consequently, each holding period (two, five, and eight hours) was analyzed separately for pressed fluid ratios. The pressed fluid ratios for "hot" versus "cold" boning were statistically different for all holding periods: two hours ($P < .01$), five hours ($P < .10$), and eight hours ($P < .025$). See Table IV (Appendix) and Figure 10.

Pressed fluid ratios may be viewed using two criteria. The larger the ratio the less the water-binding capacity of the meat (Sayre et al. 1963) or the larger the ratio the more juicy the product (Cagle 1969). However, a juicy raw product may be the exact opposite once it is cooked.

Ambient temperatures can affect the rate of pH decline. The rate of pH drop in post-mortem muscle can affect the water-binding capacity of meat (Lawrie 1966f), and ultimately the amount of pressed fluid. For the two hour holding period the "hot" boned muscles were removed from the skeleton two hours post-mortem, and were chilled immediately at 2°C. Thus, the rate of pH decrease may have been less for the "hot" boned muscles than for the intact side ("cold" boned) because reduced temperatures can slow the rate of pH decline. The slower the pH descent the less the protein denaturation and the greater the water-binding capacity of the meat. Therefore, the slower that the pH declined the smaller the resulting pressed fluid ratio. This possibly accounted for the reduced pressed fluid ratio for "hot" boning in the two hour holding period



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b]Cold boned side held 48 hours post-mortem for all holding periods.

Figure 10. Pressed Fluid Ratios for Hot Versus Cold Boning by Holding Periods

(Figure 10) as compared to the "cold" boned pressed fluid ratio. The opposite response for pressed fluid ratios for "hot" versus "cold" boning was true for the five and eight hour holding periods (Figure 10). In the five and eight hour holding periods the "hot" boned side was held intact at 16°C (ambient temperature) while the "cold" boned side was held at 2°C. The 16°C holding temperature possibly accelerated the rate of pH descent for the "hot" boned side and ultimately caused greater pressed fluid ratios for the "hot" boned side when compared to the control in the five and eight hour holding periods (Figure 10).

The pressed fluid ratios did not undergo a general increase or decrease from the two to eight hour holding periods (Figure 10). The lack of adequate humidification of the filter paper in the eight hour holding period could have accounted for the overall reduced ratios in this holding period. The humidification time in the eight hour holding period was much less than in the two and five hour holding periods.

There was a significant difference in pressed fluid ratios among muscles in all holding periods: two hours ($P < .005$), five hours ($P < .005$), and eight hours ($P < .005$). See Figure 11 and Table IV (Appendix). The boning x muscles interaction was non-significant ($P > .05$) for each holding period; therefore, the pressed fluid ratios among the muscles behaved essentially the same regardless of the boning process used (Figure 11).

In the two and five hour holding periods the pressed fluid ratios between steaks 1 and 2 in the test muscles were non-significant ($P > .05$); however, in the eight hour holding period the difference between steaks was statistically significant ($P < .005$). See Figure 12 and Table IV (Appendix). The boning x steaks in muscles interaction was

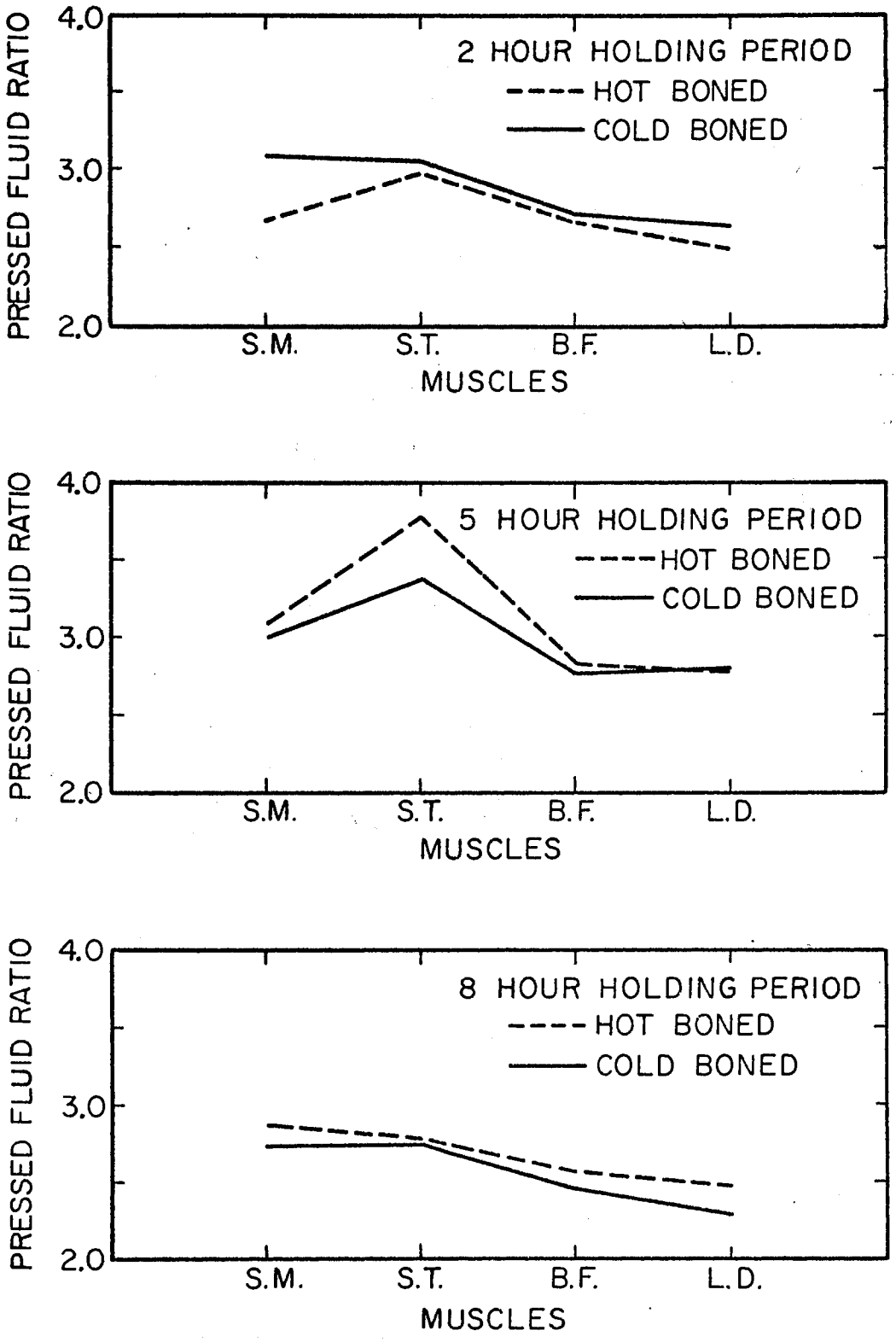


Figure 11. Pressed Fluid Ratios for Four Muscles by Boning Process

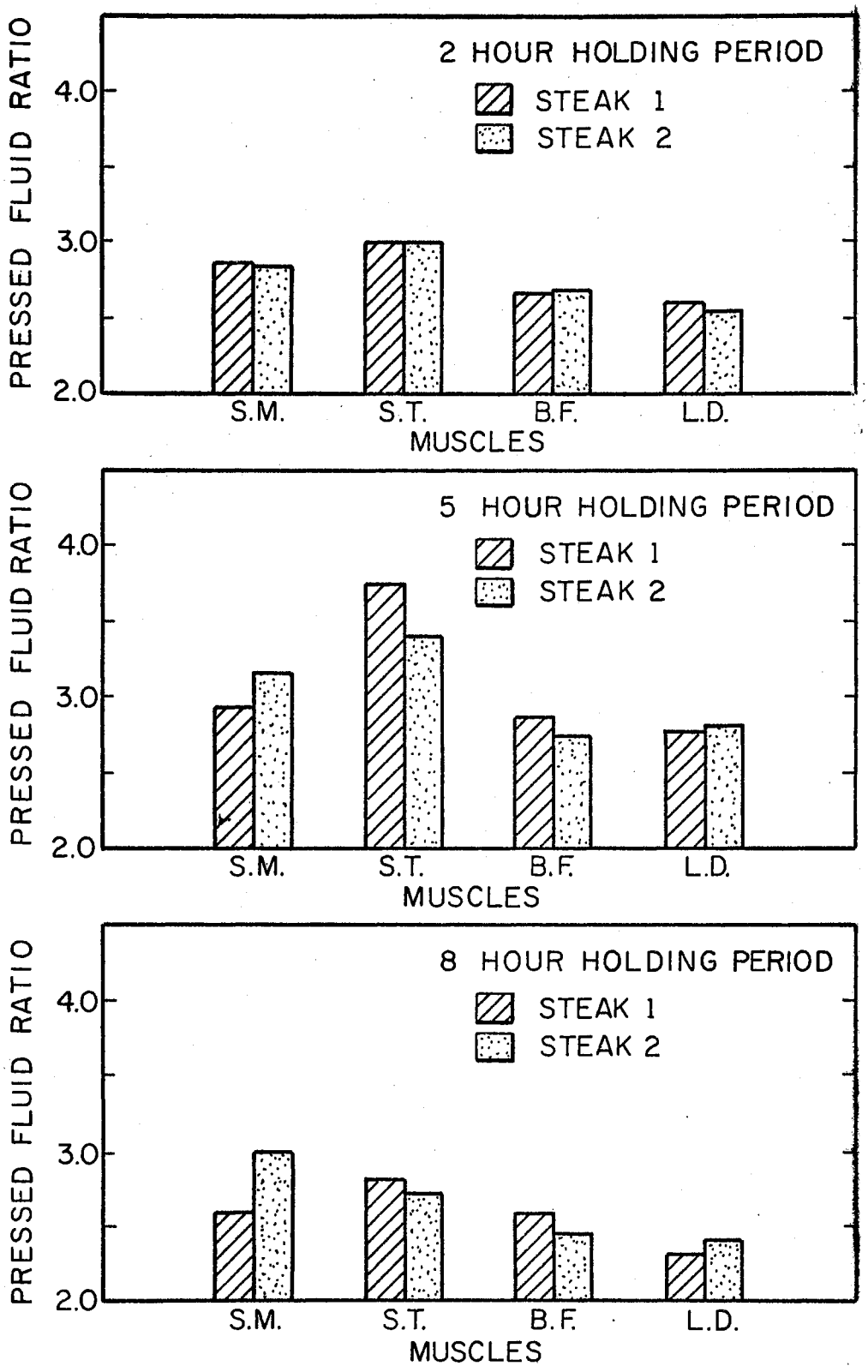


Figure 12. Pressed Fluid Ratios for Two Steaks in Four Muscles

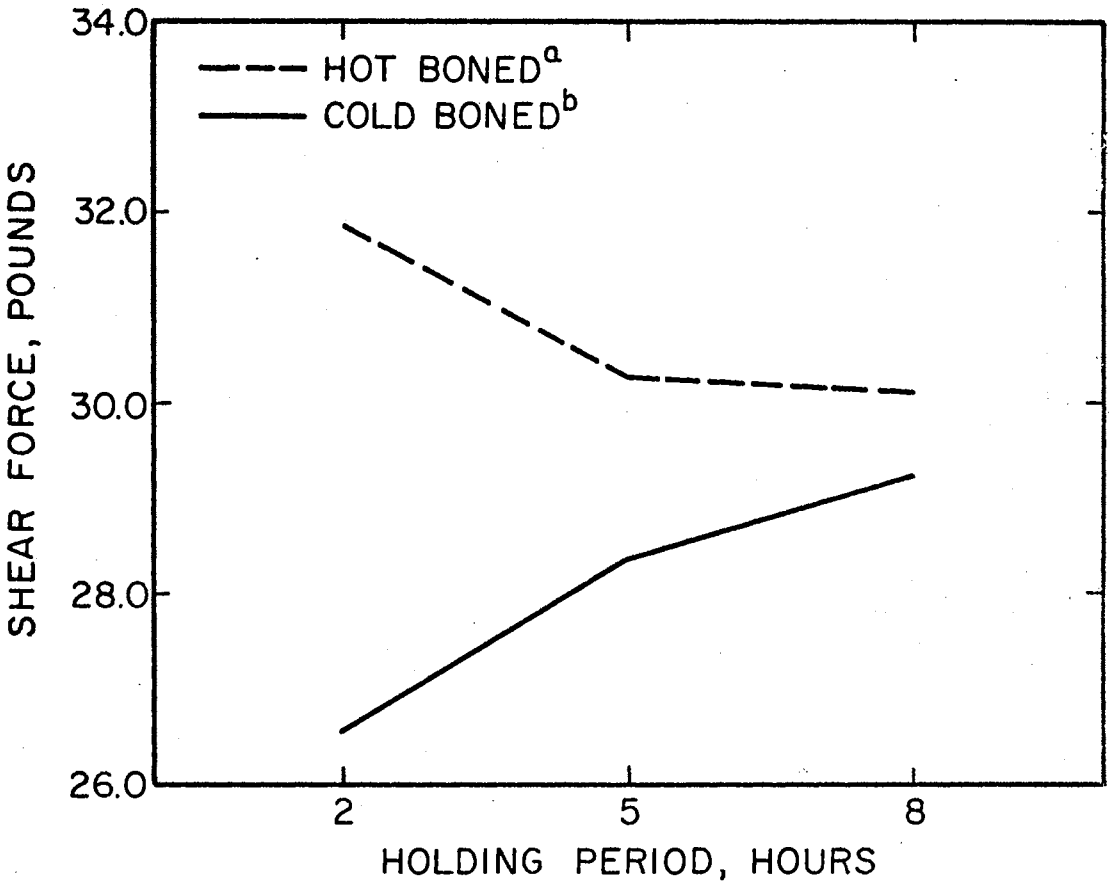
non-significant ($P > .05$) in each holding period. Thus, the relative response for pressed fluid ratios between steaks 1 and 2 in the four test muscles was the same regardless of "hot" or "cold" boning (Table IV, Appendix).

Shear Force

It appears that if muscles are held on the carcass for five to eight hours post-mortem, there is a small effect on shear force; thus, small differences between "hot" and "cold" boning with respect to tenderness would be expected.

An analysis indicated a significant ($P < .05$) holding period x boning interaction (Figure 13); therefore, each holding period was analyzed separately. The "hot" boning process and the control were statistically different in shear force for the two hour ($P < .025$) and five hour ($P < .10$) holding periods, but the differential in the eight hour holding period was non-significant ($P > .10$) (Table IV, Appendix). The conditioning time in the eight hour holding period appeared to alleviate the shear force difference between "hot" and "cold" boning. Even though the shear force differences in the two and five hour holding periods were statistically different these may not be economically important.

The ultimate pH for all carcasses was not reached prior to muscle excision of the "hot" boned side in the two hour holding period. Therefore, the difference in the shear forces for "hot" and "cold" boning in the two hour holding period (Figure 13) was due to residual metabolic activity and the resulting post-mortem muscle contraction. The ultimate pH for all carcasses in the five and eight hour holding periods was at-



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b]Cold boned side held 48 hours post-mortem for all holding periods.

Figure 13. Shear Force for Hot Versus Cold Boning by Holding Periods

tained prior to fabrication of the "hot" boned sides. However, the differential in shear force between "hot" and "cold" boning (Figure 13) indicated some residual metabolic activity.

The shear force for the "cold" boned process (Figure 13) increased from the two hour to the eight hour holding period. This trend indicated that the animals varied in quality. Product yield and percent moisture further support this trend.

Significant differences existed among shear forces in muscles in each holding period: two hours ($P < .01$), five hours ($P < .005$), and eight hours ($P < .10$) (Table IV, Appendix). In the two hour holding period there was a significant ($P < .005$) boning x muscles interaction (Table IV and Figure 14). Consequently, the relative differences in shear force among muscles in the two hour holding period were dependent on the boning process used. The relationship among muscles was contrary to data previously reported. For example, the L.D. should have been, by far, the most tender muscle of the four tested, and the inside round (S.M.) should have been more tender than the outside round (S.T. and B.F.) for all holding periods. The method of cookery possibly affected the relative tenderness and the magnitude of the shear force of the four muscles. High shear values for the S.M., S.T., and L.D. muscles were a product of the final internal temperature of the cooked steaks and the chilling period prior to shearing. One could account for the low shear forces that were found in the B.F. muscle. The test steaks in the B.F. muscle were cut parallel to the predominant flow of the muscle fibers; thus, the cores from these steaks were sheared more nearly parallel to the muscle fibers. If the entire S.M. muscle had been sampled, its relative relationship would likely have been more in line with expected

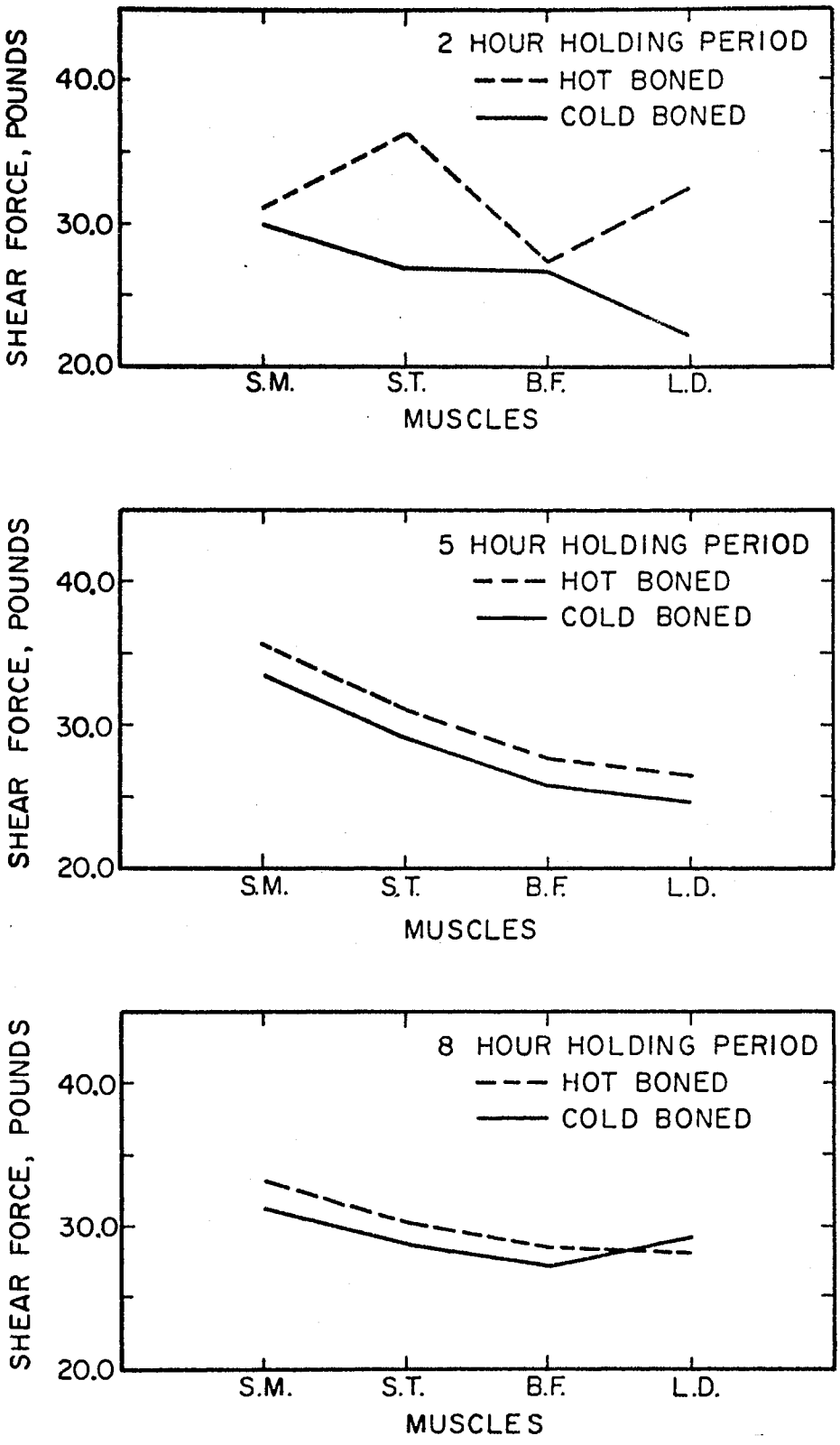


Figure 14. Shear Force for Four Muscles by Boning Process

values.

Significant shear force differences were observed between duplicate steaks in the four muscles for each of the respective holding periods: two hours ($P < .005$), five hours ($P < .005$), and eight hours ($P < .005$). The relationship between steaks can be seen in Figure 15. The boning x steaks in muscles interaction (Table IV, Appendix) was statistically non-significant ($P > .05$) for all holding periods; therefore, the responses followed similar response trends regardless of the boning process.

Color

The degree of lightness or darkness (value) of the fresh cut meat surface was used to determine if color differences existed between "hot" and "cold" boning. In general, the greater the color value score the lighter the color of the oxygenated surface of the meat. The oxygenated form of myoglobin is a lighter color (cherry-red) than the reduced form (purple).

A relatively dark product was produced by "hot" boning when compared to the control in the two hour holding period (Figure 16). However, the "cold" boned product gave smaller color value scores than the "hot" boned product in the five and eight hour holding periods (Figure 16). Even though the color value scores in the five hour and eight hour holding periods were statistically different between "hot" and "cold" boning, these differences did not manifest themselves when examined organoleptically (Table II, page 72).

An analysis indicated a significant ($P < .005$) holding period x boning interaction (Figure 16); therefore, each holding period was

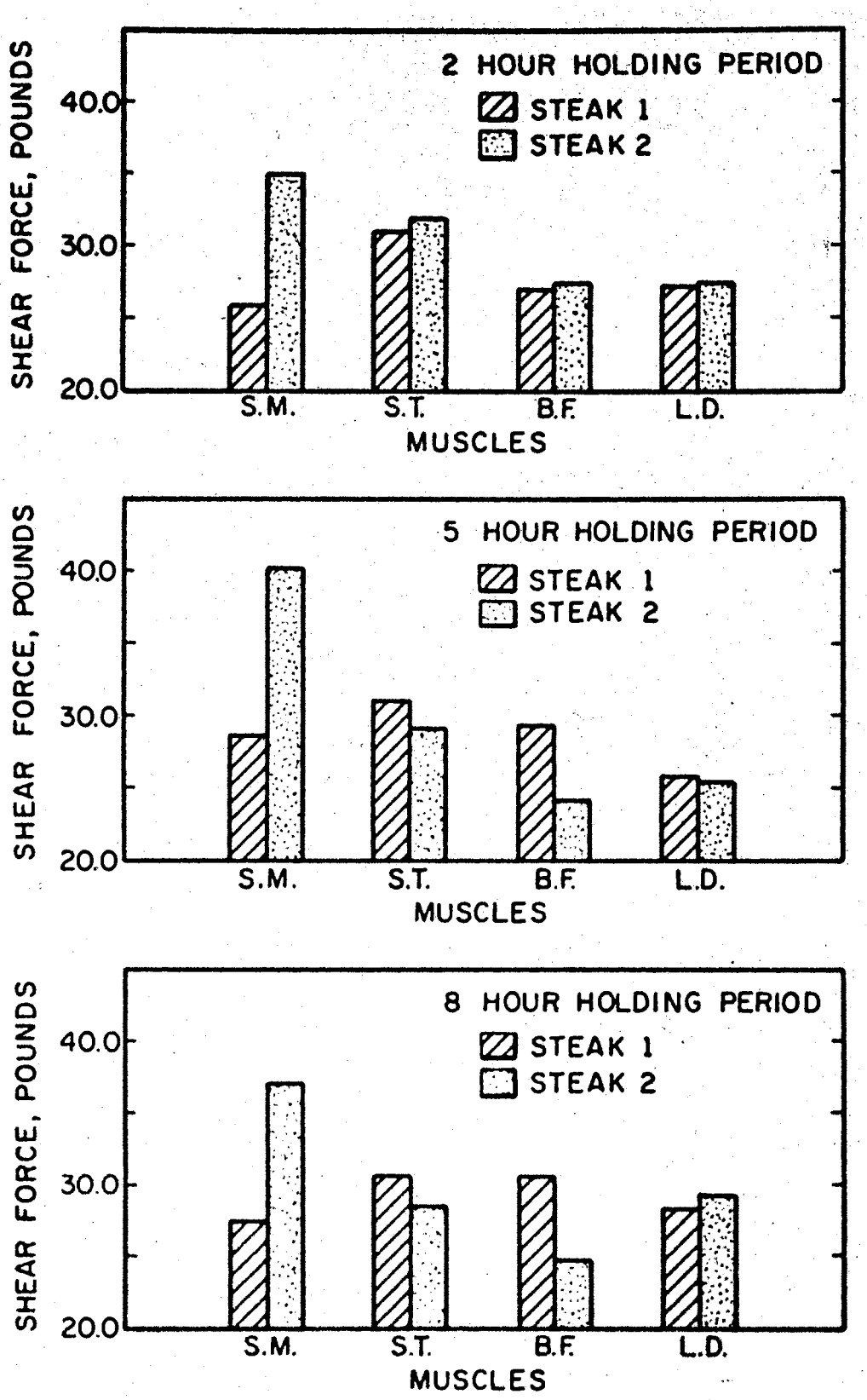
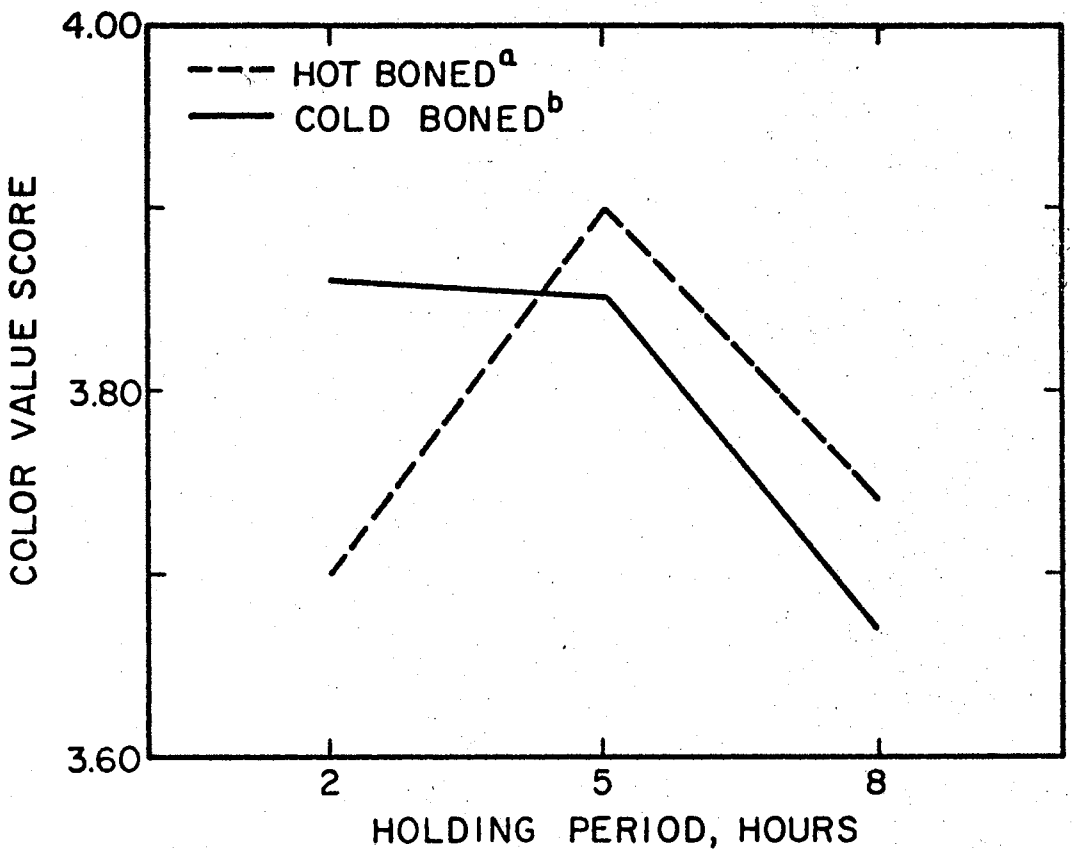


Figure 15. Shear Force for Two Steaks in Four Muscles



[a] Post-mortem holding period 2, 5, and 8 hours for hot boned side.

[b] Cold boned side held 48 hours post-mortem for all holding periods.

Figure 16. Color Value for Hot Versus Cold Boning by Holding Periods

analyzed separately. The differences in color value between "hot" and "cold" boning were statistically significant for each holding period; two hours ($P < .005$), five hours ($P < .10$), and eight hours ($P < .05$). See Figure 16 and Table IV (Appendix).

The "hot" boning process produced a darker product than the control ("cold" boning process) in the two hour holding period (Figure 16). This agreed with the fact that the shear force for "hot" boning was greater than the shear force for the "cold" boned product in the two hour holding period (Figure 13). The greater the shear force the more compact and closed the structure of the meat. Therefore, the closed structure of the "hot" boned product did not allow surface oxygenation of the myoglobin to the same extent as the relatively open structure of the "cold" boned product. Thus, the color value score for "hot" boning was less than for the control in the two hour holding period (Figure 16). The difference in shear force between "hot" and "cold" boning was much less in the five and eight hour holding periods than the two hour holding period (Figure 13). Therefore, the differences in the shear force values for "hot" versus "cold" boning in the five and eight hour holding periods (Figure 13) may not have significantly influenced the corresponding difference in color value scores (Figure 16).

It is interesting to note that pressed fluid ratios (Figure 10) for "hot" versus "cold" boning follow the same general interaction as the color values scores for "hot" and "cold" boning (Figure 16).

The "cold" boned response line for the color value scores decreased from the two hour to the eight hour holding period even though the "cold" boned sides were treated essentially the same for all holding periods (Figure 16). As intramuscular fat increases so does the color value

score of the product due to increased reflectance from the product surface. The "cold" boned response line decreased in color value from the two hour to the eight hour holding period; therefore, a decrease in intramuscular fat (marbling) was indicated. In general, as marbling decreases so does carcass quality. This indication of a general decrease in carcass quality from the two hour to the eight hour holding period corresponded to yield, percent moisture, and shear force data.

Significant differences existed for color value scores among the test muscles for all holding periods: two hours ($P < .005$), five hours ($P < .005$), and eight hours ($P < .005$). See Figure 17 and Table IV (Appendix). The boning x muscles interaction was non-significant ($P > .05$) for all holding periods; therefore, the color value differences were relatively the same among muscles regardless of the boning process used.

Color value differences for steaks 1 and 2 in the four test muscles were statistically significant for each holding period: two hours ($P < .01$), five hours ($P < .01$), and eight hours ($P < .005$) (Figure 18). For all holding periods, the relative differences in color value scores between steaks 1 and 2 in the test muscles followed similar response trends for each boning process. This is indicated by a non-significant ($P > .05$) boning x steaks in muscles interaction for each holding period (Figure 18 and Table IV, Appendix).

Percent Cooking Loss

Only the L.D. muscle was used to evaluate percent cooking loss. The differences in percent cooking loss for "hot" versus "cold" boning was non-significant ($P > .05$) for each holding period (Figure 19 and

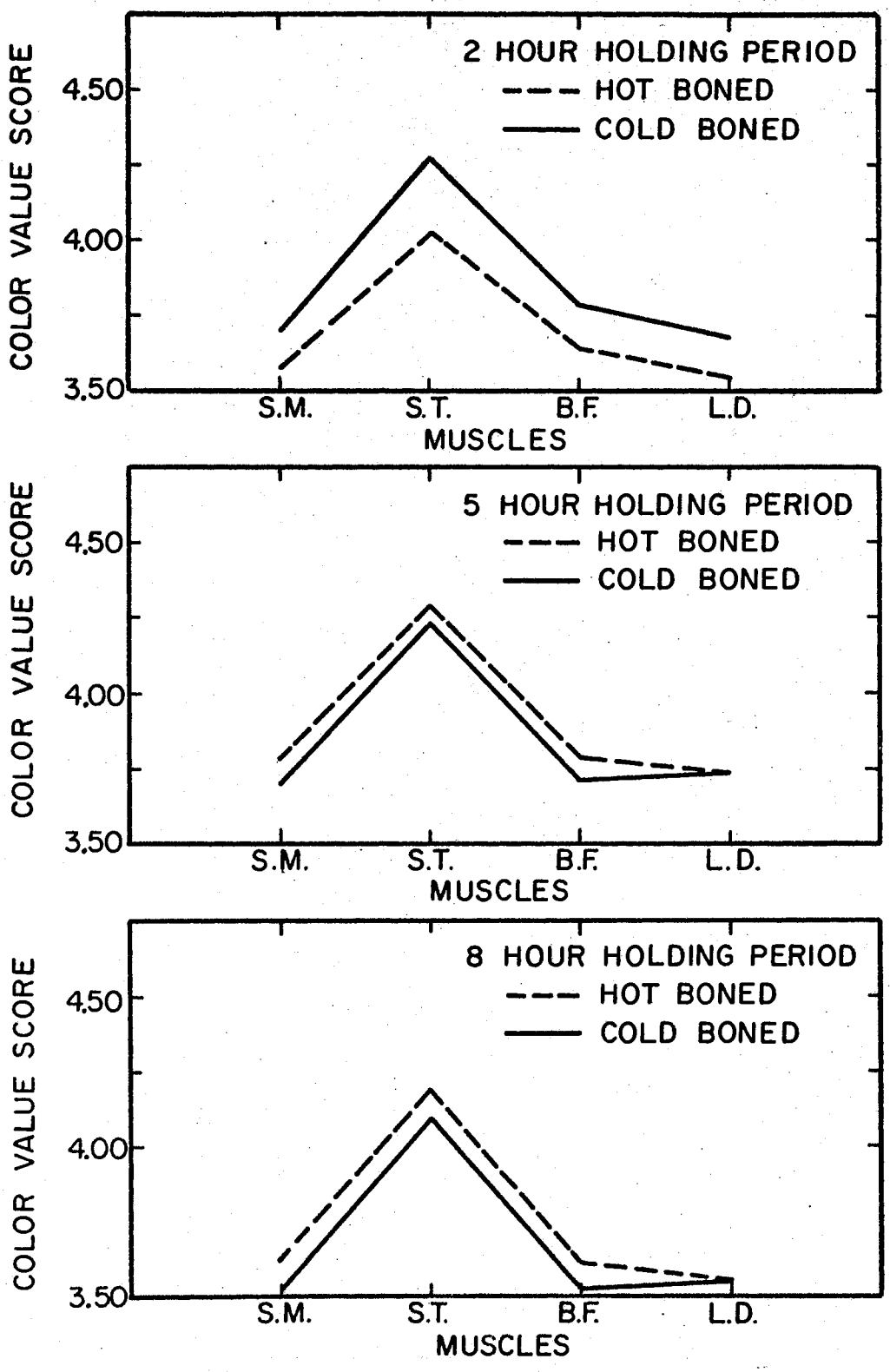


Figure 17. Color Value for Four Muscles by Boning Process

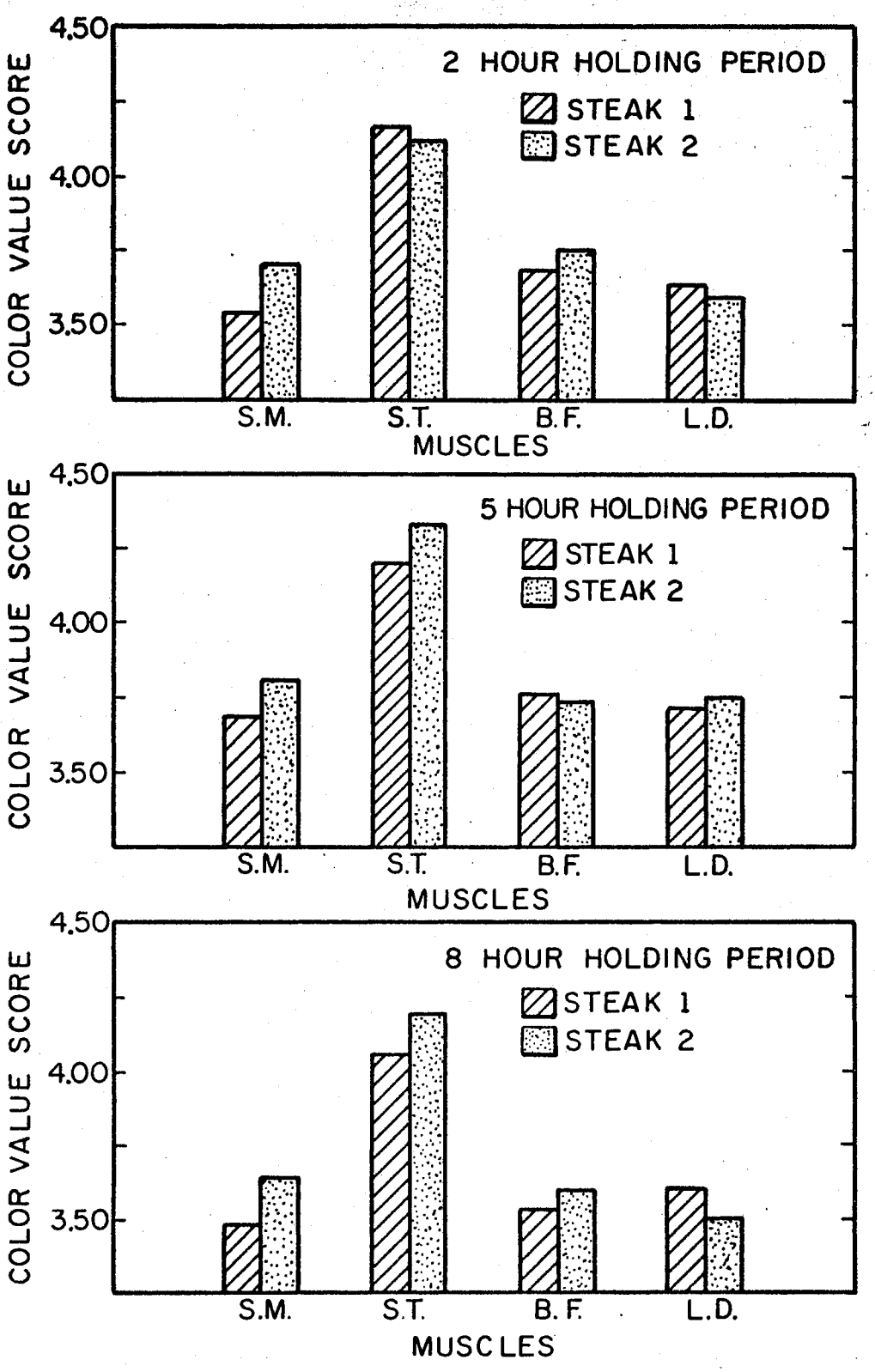
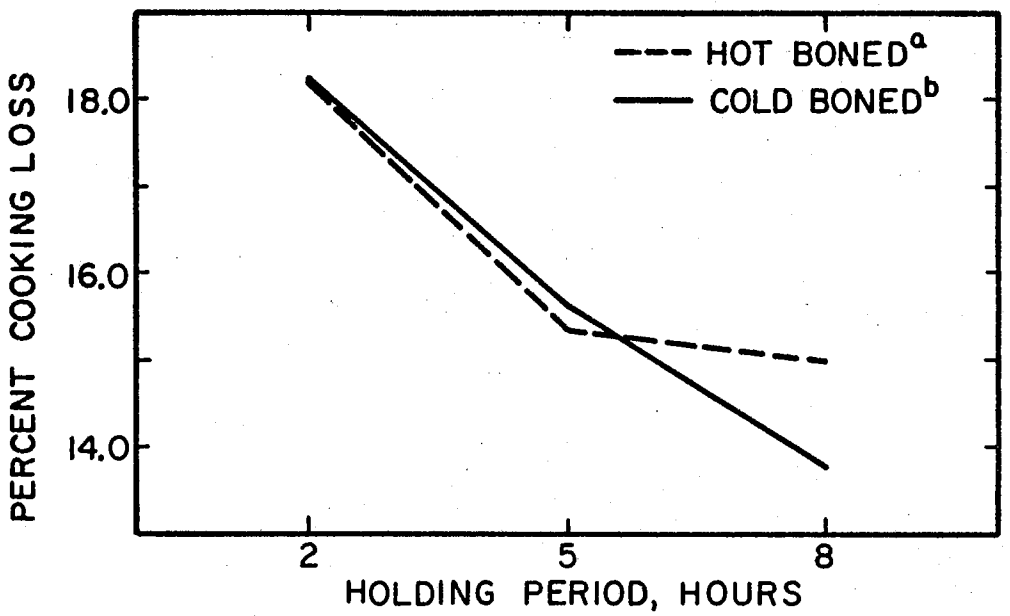
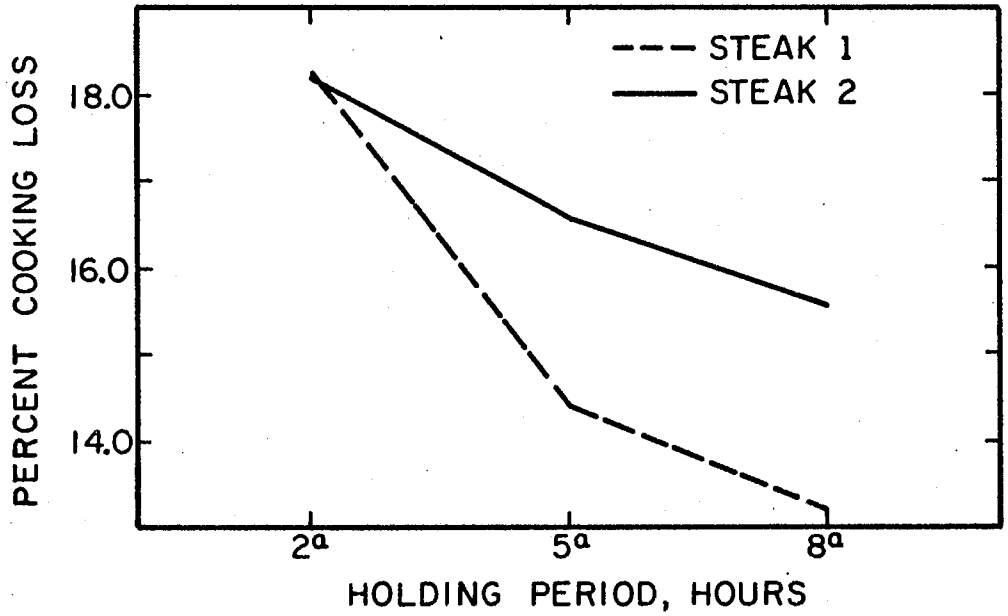


Figure 18. Color Value for Two Steaks in Four Muscles



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b]Cold boned side held 48 hours post-mortem for all holding periods.

Figure 19. Percent Cooking Loss for Hot Versus Cold Boning by Holding Periods



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.

Figure 20. Percent Cooking Loss for Two Steaks by Holding Periods

Table V, Appendix). Therefore, the percent cooking loss was not significantly affected by "hot" boning when compared to the "cold" boned process.

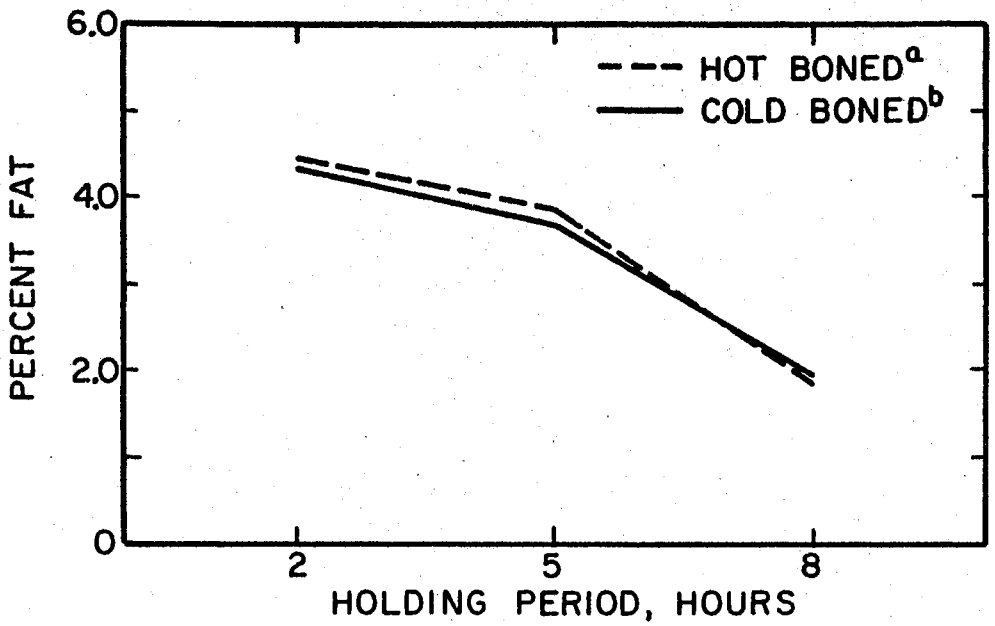
Percent cooking loss decreased from the two to the eight hour holding period for the "cold" boned product (Figure 19). This general decrease was considered to be related to the decrease in carcass quality as supported by yield, percent moisture, color, and shear force data. However, this relationship between percent cooking loss and carcass quality is difficult to rationalize.

Steaks 1 and 2 were not significantly different ($P > .05$) in percent cooking loss for the two hour holding period, but the differences were significant for the five hour ($P < .025$) and eight hour ($P < .005$) holding periods (Figure 20 and Table V, Appendix). The boning x steaks interaction was non-significant ($P > .05$) for all holding periods; thus, the boning process did not significantly affect the relative response of the percent cooking loss for steaks 1 and 2 (Table V, Appendix).

Percent Fat

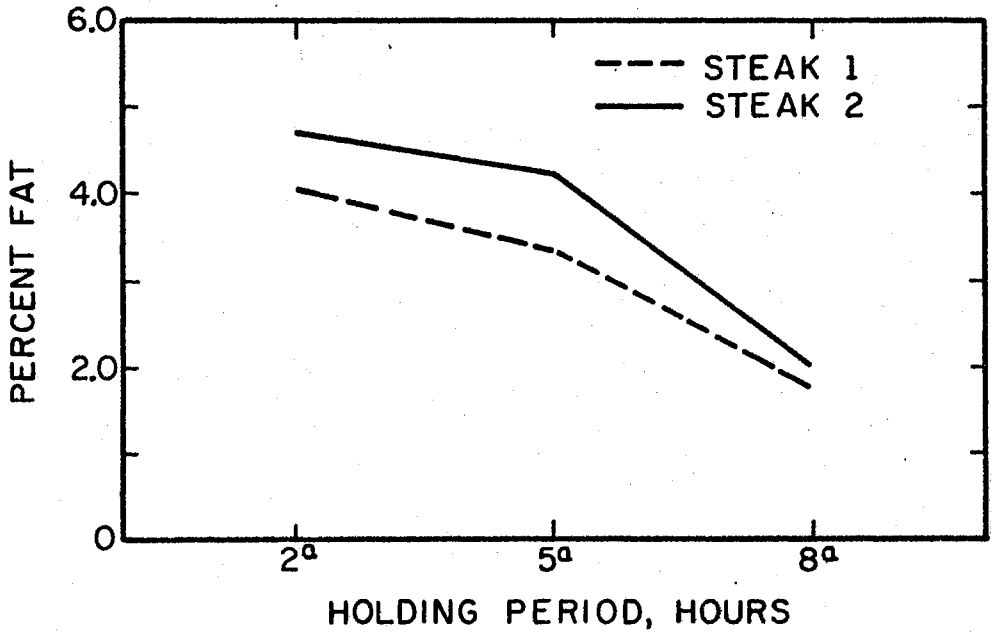
Percentage fat was determined on the L.D. muscle. The difference in percent fat between "hot" and "cold" boning was non-significant ($P > .05$) for all holding periods (Figure 21 and Table V, Appendix). This supports the non-significant differences found for percent moisture between "hot" and "cold" boning for each holding period (Figure 7 and Table IV, Appendix).

The percent fat decreased from the two to the eight hour holding period (Figure 21). This decrease in percent fat (marbling) indicated a decrease in carcass quality from the two hour to the eight hour hold-



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.
[b]Cold boned side held 48 hours post-mortem for all holding periods.

Figure 21. Percent Fat for Hot Versus Cold Boning by Holding Periods



[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.

Figure 22. Percent Fat for Two Steaks by Holding Periods

ing period. The trend for a decrease in carcass quality coincides with yield, percent moisture, color, and shear force data.

The difference in percent fat between steaks 1 and 2 was non-significant ($P > .05$) in the two and eight hour holding periods, but the difference between steaks was statistically significant ($P < .005$) in the five hour holding period (Figure 22 and Table V, Appendix). The boning x steaks interaction (Table V) was non-significant ($P > .05$) for each holding period; thus, the relative response between steaks 1 and 2 was essentially the same for each boning process.

Organoleptic Evaluation

When each holding period was considered separately, the difference in flavor between the "hot" and "cold" boned samples was statistically non-significant ($P > .05$) (Kramer and Twigg 1966). The flavor panel results are presented in Table I.

The color panel observed a significant difference ($P < .01$) in color for "hot" versus "cold" boning in the two hour holding period (Table II). This detected difference in color corresponds to the large color value difference for "hot" versus "cold" boning in the two hour holding period (Figure 16). Even though the color value scores for the five and eight hour holding periods were statistically different (Figure 16 and Table IV, Appendix), the panel was not able to visually detect a color difference (Table II).

It should be emphasized that the taste and color panels were not trained, and additional in depth subjective panel evaluation should be initiated. However, from the flavor panel results (Table I) it was concluded that flavor differences between "hot" and "cold" boning are not

TABLE I

FLAVOR PANEL RESULTS FOR HOT VERSUS COLD BONING FOR THREE HOLDING PERIODS

Holding Period	Total Number of Triangular Comparisons	Total Number Identifying Odd Sample
2 hours[a]	42	11 ns
5 hours[a]	42	13 ns
8 hours[a]	42	16 ns

[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.

ns = non-significant

TABLE II

COLOR PANEL RESULTS FOR HOT VERSUS COLD BONING FOR THREE HOLDING PERIODS

Holding Period	Total Number of Triangular Comparisons	Total Number Identifying Odd Sample
2 hours[a]	42	23 ($P < .01$)
5 hours[a]	42	15 ns
8 hours[a]	42	12 ns

[a]Post-mortem holding period 2, 5, and 8 hours for hot boned side.

ns = non-significant

likely to be apparent and would not influence the acceptability of the "hot" boning process. The color panel detected color differences in the raw product ("hot" versus "cold" boning) for the two hour holding period, but not in the five and eight hour holding periods (Table II).

CHAPTER V

SUMMARY AND CONCLUSIONS

Three holding periods (two, five, and eight hours post-mortem) with six Hereford steer carcasses in each were studied to evaluate "hot" boning as compared to conventional "cold" boning of bovine carcasses. One side of each of the 18 carcasses was assigned at random to "hot" boning and the other side was conventionally processed ("cold" boned). For all holding periods the "cold" boned side was held at 2°C for approximately 48 hours post-mortem before it was fabricated. Several yield and quality indicators were used to compare "hot" versus "cold" boning.

Percent loss was less for "hot" boning than the control for each of the conditioning periods (two, five, and eight hours). Yield as defined by percent loss was statistically different ($P < .005$) between "hot" and "cold" boning for muscles excised five and eight hour post-mortem. However, the yield difference was non-significant ($P > .05$) between "hot" and "cold" boning for the two hour conditioning period.

Percent moisture differences between "hot" and "cold" boning were non-significant ($P > .05$) for each holding period. Thus, percent loss, as an expression of yield, was a function of surface desiccation and not of moisture loss from within the muscles.

Percent fat differences for "hot" versus "cold" boning were statistically non-significant ($P > .05$) for all holding periods. This supported percent moisture data in that there was no statistical difference

($P > .05$) in percent moisture between "hot" and "cold" boning for each holding period.

Pressed fluid ratios (meat moisture) were statistically different for "hot" boning versus the "cold" boned process for all holding periods (two hours, $P < .01$; five hours, $P < .10$; and eight hours, $P < .025$). The average pressed fluid ratio for "hot" boning was less than the control for the two hour conditioning period, but more than the control when the five and eight hour conditioning periods were used.

Shear force values for the "hot" boned product were larger than in the control for all holding periods. Thus, the shear force differences between "hot" and "cold" boning were statistically significant for the two ($P < .025$) and five hour ($P < .10$) conditioning periods, but non-significant ($P > .10$) when the "hot" boned side was held eight hours before fabrication. Even though the shear force values were statistically different for "hot" and "cold" boning in the two and five hour conditioning periods, the differences might not be economically important.

Color value scores, as measured by reflectance, were significantly different in all holding periods (two hours, $P < .005$; five hours, $P < .10$; and eight hours, $P < .05$) for "hot" versus "cold" boning. For the two hour conditioning period, "hot" boning produced a darker colored product than "cold" boning. However, the "hot" boned product exhibited a brighter fresh color when conditioned for greater periods (five and eight hours).

Percent cooking loss differences for "hot" versus "cold" boning were non-significant ($P > .05$) for all holding periods.

A flavor panel could not detect any flavor difference ($P > .05$) between "hot" and "cold" boned meat.

Color panel results indicated a statistical difference ($P < .01$) between "hot" boning and the control for the two hour conditioning period, but there was no statistical difference ($P > .05$) in color for the five and eight hour holding periods.

These results indicate that "hot" boning is feasible from the standpoint of the parameters tested when the "hot" boned product is held intact for five to eight hours post-mortem and treated as outlined in this study. Tenderness and yield do not appear to be problem areas with the proposed process. In addition, when a carcass was boned "hot", fabrication time was decreased because the fat was pliable, and the muscles and muscle systems were easily excised.

Additional research should be initiated to further evaluate "hot" boning.

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APPENDIX

Some means reported in this study have been corrected and are different from the values originally analyzed. The decimal points were positioned in order that the effect of the computer rounding error would be of little consequence. In order to obtain the original values that were statistically analyzed move the decimal point as outlined below:

1. Yield is correct as reported.
2. Pressed fluid ratios should have the decimal point moved one place to the right.
3. Percent moisture means should have the decimal point moved one place to the right.
4. Shear force means are correct as reported.
5. Color value means should have the decimal point moved one place to the right.
6. Percent fat means should have the decimal point moved two places to the right.
7. Percent cooking loss means are correct as reported.

TABLE III

ANALYSIS OF VARIANCE FOR PERCENT LOSS FOR THREE HOLDING PERIODS

Holding Periods	Variance Source	D.F.	M.S.	F
2 hours	Corrected Total	11	0.2317	
	Animal	5	0.2508	ns
	Boning	1	0.1408	ns
	Animal x Boning (Error)	5	0.2308	
5 hours	Corrected Total	11	0.5997	
	Animal	5	0.1833	ns
	Boning	1	4.8133	(P < .005)
	Animal x Boning (Error)	5	0.1733	
8 hours	Corrected Total	11	1.6184	
	Animal	5	0.0815	ns
	Boning	1	17.0408	(P < .005)
	Animal x Boning (Error)	5	0.0708	

ns = non-significant

TABLE IV

ANALYSIS OF VARIANCE FOR PRESSED FLUID RATIOS, SHEAR FORCE, PERCENT MOISTURE, AND COLOR VALUE

Variance Source	Pressed Fluid Ratios			Shear Force			Percent Moisture			Color Value		
	D.F.	M.S.	F	D.F.	M.S.	F	D.F.	M.S.	F	D.F.	M.S.	F
Corrected Total	863	28.2817	-----	863	55.5875	-----	575	173.0452	-----	287	9.5369	-----
Holding Periods	2	1430.0413	(P < .010)	2	14.6710	ns	2	4830.4505	ns	2	69.1095	ns
A in HP2 E(A_1)	5	119.1540	(P < .025)	5	706.6428	(P < .100)	5	1278.1064	(P < .005)	5	56.1954	(P < .005)
A in HP5 E(A_2)	5	461.6489	(P < .005)	5	619.2678	(P < .025)	5	5384.3279	(P < .005)	5	35.6829	(P < .005)
A in HP8 E(A_3)	5	90.5479	(P < .010)	5	707.2275	(P < .005)	5	924.6625	(P < .005)	5	15.8742	(P < .025)
Pooled E(A)	15	223.7836	-----	15	677.7127	-----	15	2529.0323	-----	15	35.9175	-----
B in HP2	1	222.0776	(P < .010)	1	1976.1085	(P < .025)	1	9.6306	ns	1	63.3751	(P < .005)
B in HP5	1	129.2027	(P < .100)	1	267.7683	(P < .100)	1	65.8010	ns	1	6.6676	(P < .100)
B in HP8	1	88.2235	(P < .025)	1	49.5013	ns	1	0.2930	ns	1	11.8301	(P < .050)
A x B in HP2 E(B_1)	5	12.5731	-----	5	153.6213	-----	5	27.0571	-----	5	0.6090	-----
A x B in HP5 E(B_2)	5	24.4396	-----	5	64.1049	-----	5	74.9724	-----	5	1.1429	-----
A x B in HP8 E(B_3)	5	7.0169	-----	5	32.8108	-----	5	31.6990	-----	5	1.4523	-----
Pooled E(B)	15	14.6765	-----	15	83.5123	-----	15	44.5762	-----	15	1.0681	-----
M in HP2	3	273.0891	(P < .005)	3	363.8357	(P < .010)	3	1652.7470	(P < .005)	3	147.5763	(P < .005)
M in HP5	3	975.5435	(P < .005)	3	1149.4652	(P < .005)	3	2175.1971	(P < .005)	3	164.3457	(P < .005)
M in HP8	3	299.5760	(P < .005)	3	274.2882	(P < .100)	3	872.2177	(P < .005)	3	198.0336	(P < .005)
B x M in HP2	3	53.4748	ns	3	511.0498	(P < .005)	3	73.5257	ns	3	1.7742	ns
B x M in HP5	3	50.3240	ns	3	0.3880	ns	3	26.2816	ns	3	1.1868	ns
B x M in HP8	3	6.1304	ns	3	37.6034	ns	3	49.2354	ns	3	1.0821	ns
(A x M + A x B x M) in HP2 E(C_1)	30	32.6270	-----	30	73.8202	-----	30	245.3967	-----	30	2.9354	-----
(A x M + A x B x M) in HP5 E(C_2)	30	64.9751	-----	30	37.2400	-----	30	111.4805	-----	30	2.0560	-----
(A x M + A x B x M) in HP8 E(C_3)	30	13.1796	-----	30	72.4725	-----	30	49.4002	-----	30	0.9958	-----
Pooled E(C)	90	36.9272	-----	90	61.1775	-----	90	135.4258	-----	90	1.9957	-----
S in M in HP2	4	2.9973	ns	4	373.6887	(P < .005)	4	1155.1819	(P < .005)	4	6.1268	(P < .010)
S in M in HP5	4	84.3015	ns	4	729.3944	(P < .005)	4	1618.7297	(P < .005)	4	5.8307	(P < .010)
S in M in HP8	4	87.9846	(P < .005)	4	604.6578	(P < .005)	4	872.5351	(P < .005)	4	8.4240	(P < .005)
B x S in M in HP2	4	21.7392	ns	4	36.7482	ns	4	24.9060	ns	4	2.3906	ns
B x S in M in HP5	4	5.4063	ns	4	7.0537	ns	4	22.7582	ns	4	0.8603	ns
B x S in M in HP8	4	5.3457	ns	4	15.7852	ns	4	26.5831	ns	4	0.1878	ns
(AxSinM+AxBxS in M) in HP2 E(D_1)	40	18.4391	-----	40	47.6814	-----	40	130.1788	-----	40	1.5502	-----
(AxSinM+AxBxS in M) in HP5 E(D_2)	40	98.9065	-----	40	21.0333	-----	40	49.3000	-----	40	1.4045	-----
(AxSinM+AxBxS in M) in HP8 E(D_3)	40	11.3609	-----	40	15.1412	-----	40	47.9253	-----	40	0.6784	-----
Pooled E(D)	120	42.9022	-----	120	27.9520	-----	120	75.8014	-----	120	1.2111	-----
Cores or Duplicates in S in M in B in A in Holding Periods	576	5.6483	-----	576	19.6033	-----	288	1.5464	-----	---	-----	-----
	General Mean = 2.8234			General Mean = 29.3866			General Mean = 73.8789			General Mean = 3.7904		

A = Animals
HP2 = Two hour holding period
HP5 = Five hour holding period
HP8 = Eight hour holding period
E = Error
B = Boning
M = Muscles
S = Steaks
ns = non-significant

TABLE V

ANALYSIS OF VARIANCE FOR PERCENT FAT AND PERCENT COOKING LOSS

Variance Source	Percent Fat			Percent Cooking Loss		
	D.F.	M.S.	F	D.F.	M.S.	F
Corrected Total	143	25420.8911	-----	71	7.5824	-----
Holding Periods	2	804911.1971	(P < .005)	2	92.4154	(P < .005)
A in HP2 $E(A_1)$	5	70996.2217	(P < .050)	5	5.3524	ns
A in HP5 $E(A_2)$	5	169101.6011	(P < .005)	5	11.5414	ns
A in HP8 $E(A_3)$	5	49236.9704	(P < .010)	5	8.0574	ns
Pooled E(A)	15	96444.9311	-----	15	8.3171	-----
B in HP2	1	1586.9979	ns	1	0.0338	ns
B in HP5	1	2363.2262	ns	1	0.5104	ns
B in HP8	1	448.3514	ns	1	8.5204	ns
A x B in HP2 $E(B_1)$	5	12019.5012	-----	5	7.8077	-----
A x B in HP5 $E(B_2)$	5	7824.7060	-----	5	4.8454	-----
A x B in HP8 $E(B_3)$	5	3556.7848	-----	5	2.5594	-----
Pooled E(B)	15	7800.3307	-----	15	5.0708	-----
S in HP2	1	51640.3016	ns	1	0.0337	ns
S in HP5	1	95711.7607	(P < .005)	1	26.6703	(P < .025)
S in HP8	1	9749.8486	ns	1	32.9003	(P < .005)
B x S in HP2	1	357.5218	ns	1	0.0937	ns
B x S in HP5	1	338.1394	ns	1	8.2838	ns
B x S in HP8	1	276.9604	ns	1	2.6004	ns
(A x S + A x B x S) in HP2 $E(C_1)$	10	18084.9665	-----	10	2.4047	-----
(A x S + A x B x S) in HP5 $E(C_2)$	10	6849.5945	-----	10	3.2151	-----
(A x S + A x B x S) in HP8 $E(C_3)$	10	4209.2002	-----	10	1.6854	-----
Pooled E(C)	30	9714.5870	-----	30	2.4351	-----

TABLE V (Continued)

Variance Source	Percent Fat			Percent Cooking Loss		
	D.F.	M.S.	F	D.F.	M.S.	F
Duplicates in S in B in A in Holding Periods	72	107.9915	-----	--	-----	-----
	General Mean = 3.3512			General Mean = 16.0236		

A = Animals
HP2 = Two hour holding period
HP5 = Five hour holding period
HP8 = Eight hour holding period
E = Error
B = Boning
S = Steaks
ns = non-significant

TABLE VI

MEANS FOR PERCENT LOSS

Boning Process	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	2	6	1.9833	5	6	1.2500	8	6	0.3833
Cold	2	6	2.2000	5	6	2.5167	8	6	2.7667

TABLE VII

MEANS FOR PERCENT FAT AND PERCENT COOKING LOSS

Percent Fat

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	L.D.	1	2	12	4.0837	5	12	3.4247	8	12	1.7005
Cold	L.D.	1	2	12	4.0233	5	12	3.2313	8	12	1.8096
Hot	L.D.	2	2	12	4.7943	5	12	4.2647	8	12	2.0335
Cold	L.D.	2	2	12	4.6247	5	12	4.1774	8	12	2.0466

Percent Cooking Loss

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	L.D.	1	2	6	18.1333	5	6	14.8833	8	6	14.1333
Cold	L.D.	1	2	6	18.3333	5	6	14.0000	8	6	12.2833
Hot	L.D.	2	2	6	18.1833	5	6	15.8167	8	6	15.8167
Cold	L.D.	2	2	6	18.1333	5	6	17.2833	8	6	15.2833

TABLE VIII

MEANS FOR PERCENT MOISTURE AND PRESSED FLUID RATIOS

Percent Moisture

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	S.M.	1	2	12	73.2608	5	12	73.3241	8	12	74.1041
Cold	S.M.	1	2	12	73.3049	5	12	73.6274	8	12	74.1033
Hot	S.T.	1	2	12	73.4524	5	12	73.6541	8	12	74.1291
Cold	S.T.	1	2	12	73.2874	5	12	74.0824	8	12	74.2541
Hot	B.F.	1	2	12	72.6699	5	12	73.0541	8	12	73.7166
Cold	B.F.	1	2	12	72.5474	5	12	72.8716	8	12	73.1974
Hot	L.D.	1	2	12	72.9558	5	12	73.5341	8	12	74.5599
Cold	L.D.	1	2	12	73.2783	5	12	73.8083	8	12	74.5699
Hot	S.M.	2	2	12	74.8299	5	12	75.2458	8	12	74.8899
Cold	S.M.	2	2	12	74.4633	5	12	75.2624	8	12	75.2441
Hot	S.T.	2	2	12	74.5424	5	12	74.9924	8	12	75.3399
Cold	S.T.	2	2	12	74.0999	5	12	75.0849	8	12	75.4408
Hot	B.F.	2	2	12	73.3483	5	12	73.4608	8	12	74.1699
Cold	B.F.	2	2	12	73.5008	5	12	73.4633	8	12	74.1274
Hot	L.D.	2	2	12	72.3591	5	12	72.8866	8	12	74.2924
Cold	L.D.	2	2	12	72.5783	5	12	72.8883	8	12	74.3274

Pressed Fluid Ratios

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	S.M.	1	2	18	2.7322	5	18	2.9950	8	18	2.6888
Cold	S.M.	1	2	18	3.0550	5	18	2.8644	8	18	2.5122
Hot	S.T.	1	2	18	2.8866	5	18	3.9755	8	18	2.7922
Cold	S.T.	1	2	18	3.1088	5	18	3.5272	8	18	2.8333
Hot	B.F.	1	2	18	2.6094	5	18	2.8805	8	18	2.6044
Cold	B.F.	1	2	18	2.7400	5	18	2.8722	8	18	2.5427
Hot	L.D.	1	2	18	2.4866	5	18	2.7816	8	18	2.4000
Cold	L.D.	1	2	18	2.7405	5	18	2.7805	8	18	2.2627
Hot	S.M.	2	2	18	2.6100	5	18	3.1877	8	18	3.0427
Cold	S.M.	2	2	18	3.1394	5	18	3.1500	8	18	2.9688
Hot	S.T.	2	2	18	3.0550	5	18	3.5716	8	18	2.7877
Cold	S.T.	2	2	18	3.0033	5	18	3.2650	8	18	2.6844
Hot	B.F.	2	2	18	2.7211	5	18	2.8161	8	18	2.5372
Cold	B.F.	2	2	18	2.6777	5	18	2.6688	8	18	2.3683
Hot	L.D.	2	2	18	2.5244	5	18	2.8127	8	18	2.5377
Cold	L.D.	2	2	18	2.5655	5	18	2.8211	8	18	2.3327

TABLE IX

MEANS FOR SHEAR FORCE AND COLOR VALUE

Shear Force

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	S.M.	1	2	18	26.6833	5	18	29.6778	8	18	28.1444
Cold	S.M.	1	2	18	25.4389	5	18	28.0278	8	18	26.8778
Hot	S.T.	1	2	18	34.6055	5	18	32.3722	8	18	31.7500
Cold	S.T.	1	2	18	27.9833	5	18	29.6833	8	18	29.3944
Hot	B.F.	1	2	18	26.8278	5	18	29.8722	8	18	30.7666
Cold	B.F.	1	2	18	27.3833	5	18	28.7500	8	18	30.7278
Hot	L.D.	1	2	18	32.5389	5	18	26.8389	8	18	27.3278
Cold	L.D.	1	2	18	22.0833	5	18	25.0278	8	18	29.2666
Hot	S.M.	2	2	18	35.7000	5	18	41.6833	8	18	38.5278
Cold	S.M.	2	2	18	34.5833	5	18	39.0778	8	18	35.9722
Hot	S.T.	2	2	18	38.0778	5	18	29.6611	8	18	28.6444
Cold	S.T.	2	2	18	25.9167	5	18	28.6167	8	18	28.2722
Hot	B.F.	2	2	18	27.7944	5	18	25.6389	8	18	26.2500
Cold	B.F.	2	2	18	27.0000	5	18	22.8889	8	18	23.6000
Hot	L.D.	2	2	18	32.4278	5	18	26.4167	8	18	29.0389
Cold	L.D.	2	2	18	22.3555	5	18	24.6611	8	18	29.7055

Color Value

Boning Process	Muscle	Steak	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean	Holding Period (Hours)	Observations	Mean
Hot	S.M.	1	2	6	3.5416	5	6	3.7300	8	6	3.5300
Cold	S.M.	1	2	6	3.5516	5	6	3.6316	8	6	3.4550
Hot	S.T.	1	2	6	4.0650	5	6	4.1916	8	6	4.1133
Cold	S.T.	1	2	6	4.2783	5	6	4.2150	8	6	4.0333
Hot	B.F.	1	2	6	3.6150	5	6	3.8116	8	6	3.5833
Cold	B.F.	1	2	6	3.7816	5	6	3.7283	8	6	3.4966
Hot	L.D.	1	2	6	3.5850	5	6	3.7150	8	6	3.6183
Cold	L.D.	1	2	6	3.7133	5	6	3.7300	8	6	3.5883
Hot	S.M.	2	2	6	3.6016	5	6	3.8650	8	6	3.7150
Cold	S.M.	2	2	6	3.8533	5	6	3.7683	8	6	3.5866
Hot	S.T.	2	2	6	3.9883	5	6	4.4016	8	6	4.2533
Cold	S.T.	2	2	6	4.2616	5	6	4.2766	8	6	4.1616
Hot	B.F.	2	2	6	3.6883	5	6	3.7700	8	6	3.6450
Cold	B.F.	2	2	6	3.8133	5	6	3.7133	8	6	3.5600
Hot	L.D.	2	2	6	3.5266	5	6	3.7566	8	6	3.5000
Cold	L.D.	2	2	6	3.6583	5	6	3.7566	8	6	3.5150

VITA

Curtis Lynn Kastner

Candidate for the Degree of

Doctor of Philosophy

Thesis: INFLUENCE OF "HOT" BONING ON BOVINE MUSCLE

Major Field: Food Science

Biographical:

Personal Data: Born in Altus, Oklahoma, September 21, 1944, the son of Carlus and Darlene Kastner. Married Rebecca Jon Diltz, August 6, 1966.

Education: Graduated from Altus High School in 1962. Attended Oklahoma State University and graduated with the Bachelor of Science degree in May, 1967, with a major in Hotel and Restaurant Administration. Received the Master of Science degree in Food Science in May, 1969, from Oklahoma State University.

Professional Experience: Student supervisor for Resident Halls Food Service, Oklahoma State University, 1966-67. Summer employee 1967 at Armour and Company Food Research Division, Oak Brook, Illinois. Graduate Research and Teaching Assistant in Food Science, Oklahoma State University 1967-71.

Professional Organizations: Member of Institute of Food Technologists and of Society of Sigma Xi.