THE EFFECT OF ELECTRICAL STIMULATION AND HOT BONING ON BEEF TENDERNESS

By

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CHAPTER I

INTRODUCTION

With the rising cost of labor and energy and the depletion of natural resources, the meat industry is being forced to look into new and different processing methods. Meat must move to the consumer more rapidly and efficiently. Refrigeration space and processing time will need to be conserved. Processing labor will need to be more efficient.

The meat industry is facing these new challenges and demands. Portion control has reduced waste and is labor saving. Centralized cutting is also an energy saving and labor reducing process. The next step appears to be the development of more efficient fabrication methods. Researchers' answer to this step appears to be delayed chilling and "hot" processing, which is the separation of edible meat from bone prior to chilling.

Research is moving ahead at a fast pace to develop the "hot" boning process and to study its effectiveness. In 1962, researchers began studying the tenderness of muscles processed pre-rigor (Reddy, 1962). By 1969 active examination of "hot" processed pork was underway (Barbe et al., 1966; Barbe and Henrickson, 1967; Mandigo and

Henrickson, 1966; Henrickson, 1968). No evidence was found to discriminate against "hot" processing of cured ham after evaluating bacterial count, yield, tenderness, juiciness, flavor, and moisture content (Mandigo and Henrickson, 1966; Henrickson, 1968). By 1974 it was found feasible to "hot" process beef (Schmidt and Gilbert, 1970; Brasington and Hammons, 1971; Kastner et al., 1972; Brasington and Hammons, 1972; Parrish et al., 1973; Falk and Henrickson, 1974; Schmidt and Kenman, 1974).

Henrickson, in 1974, proposed several possible advantages for "hot" boning beef. First, there would be less required energy for cooling, since the waste fat and bone would be separated from the edible tissue prior to chilling. This would allow the lean tissue to chill more rapidly. Second, on-the-line muscle separation could reduce meat spoilage, as properly handled meat would have a lower microbial contamination potential. Third, when the edible tissue is separated from the carcass, it may be placed in Cry-O-Vac bags. This could decrease weight loss from evaporation and thereby increase yield of edible boneless meat. An additional advantage would be the reduction of expensive refrigeration facilities, because less space would be required around, above, and below the muscles as compared to a carcass. Also, transportation and processing costs would be reduced as overhead rail transportation of sides and quarters is eliminated. Finally, the boneless, closely trimmed product that results from delayed chilling lends itself well to further processing.

To evaluate the effectiveness of a new processing technique, tenderness of the final product must be considered, since the consumer rates meat tenderness as the major attribute of eating quality (Lawrie, 1968b). The tenderness of delayed chilled beef was examined in a study by Will et al. (1976). It was concluded that a 3-hour, delayed-chill hold period is the minimum time allowable to maintain tenderness at a comparable level of acceptance to conventionally processed beef.

The objective of this study was to examine the possibility of shortening the time of delayed chilling to less than three hours post-mortem using electric stimulation while maintaining an acceptable level of tenderness as measured by physical evaluation--Warner-Bratzler Shear--and subjective evaluation--tenderness taste panel.

CHAPTER II

LITERATURE REVIEW

Tenderness is one of the most important quality characteristics of meat, since it, along with flavor, juiciness, and color, is used by the consumer to judge the eating quality. Because tenderness is a major quality attribute, it is necessary that it be thoroughly examined when evaluating the effectiveness of a new processing technique.

The degree and level of tenderness in meat is governed by two distinct groups of characteristics. One group consists of qualities inherent in the live animal, such as age, sex, breed, conformation, and pre-slaughter treatment. The second group of characteristics develop post-slaughter with the conversion of muscle to meat.

A series of complex post-mortem physical and chemical changes occur in the conversion of muscle to meat over a relatively short time period. The rate and extent to which these post-mortem changes proceed exert a strong influence on many important physical properties of meat and meat products (Forrest et al., 1969).

Chemical Changes

Two very prominent chemical changes occur after death: a loss of

ATP and a drop in pH. These two changes are closely interrelated in the transformation of muscle to meat before the onset of rigor mortis.

In a live animal, the muscle environment is aerobic, and glucose is continually transported into the cells of the body to provide metabolic energy for growth and muscle activity. Upon death of the animal, the efficient production of metabolic energy drops rapidly, and anaerobic glycolysis occurs. Creatine phosphate and glycogen both serve as the energy sources for this glycolysis.

Glycogen, a basic carbohydrate reserve in muscle, breaks down by glycolysis to form lactic acid and produces a small amount of ATP. As the amount of lactic acid builds up in the cell, the pH decreases from about 7.4 to about 5.3. Bate-Smith and Bendall (1949) stated that an ultimate pH of 5.3 appeared to be a limiting value, beyond which glycolysis is completely inhibited.

The breakdown of creatine phosphate serves as a mechanism for the conversion of ATP from ADP. However, the amount of creatine phosphate present in muscle is so small that it quickly depletes and provides very little ATP for energy.

In 1951, Bendall showed that creatine phosphate was the first biochemical compound to be broken down during the course of rigor mortis in rested muscles at 37° C and 17° C. ATP appeared to start breaking down when 70% or more creatine phosphate had disappeared. As with earlier investigations, ATP was found to diminish rather quickly, depending upon how rapidly glycolysis proceeded. With no

more ATP being produced by glycolysis or breakdown of creatine phosphate, the ATP rapidly disappears from muscle and the muscle fibers lose their extensibility and shorten.

The critical level of ATP at which shortening begins depends upon the ultimate pH of the muscle and the rate of decline before onset of rigor mortis. Rigor mortis onset was found by Briskey et al. (1962) to vary from two minutes to eight hours in porcine muscle. Marsh (1954) defined the onset of rigor mortis in beef to be when all glycolitic processes were completed, about 36 hours. Smith et al. (1969) found that shortening due to rigor mortis was completed within three hours in chickens and five hours in turkey muscles. Complete loss of extensibility in turkey Pectoralis muscle was accomplished 25 to 390 minutes post-mortem (T-I Ma et al., 1971). Sayre and Briskey (1963) used a 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 death. It was demonstrated by deFremery and Pool (1960) that the more rapid the onset of rigor mortis (whether measured by breakdown of ATP, glycogen, or drop in pH) the less tender will be the subsequently cooked Pectoralis major muscle in poultry. The pH decline in muscle post-mortem has been used by several researchers to follow the time course of rigor mortis and tenderness. Extensive glycolysis immediately before or during slaughter and bleeding of poultry caused low post-slaughter pH, rapid cessation of post-mortem glycolysis, rapid onset of rigor mortis, and

toughness (Khan and Nakamura, 1970). Glycolysis and dephosphorylation of high energy phosphates occurring in beef just before or during slaughter and a rapid rate of post-mortem pH change play major roles in determining the progress of post-mortem tenderization and ultimate tenderness (Khan and Lentz, 1973). Bouton et al. (1957) found that as the ultimate pH increased from 5.5 to 6.0, tenderness appeared to decrease in the bovine carcass. However, at ultimate pH levels above 6.0, tenderness in the bovine carcass increased. The trend of decreased tenderness with increased ultimate pH does not hold true for other species, such as rabbit (Miles and Lawrie, 1970), sheep (Bouton et al., 1971), and fish (Kelley et al., 1966). Tenderness in those species has been shown to increase with higher ultimate pH.

The rate of pH decline is related to temperature (Bate-Smith and Bendall, 1949; Bendall, 1951; Marsh, 1954; Marsh and Thompson, 1957; Bendall, 1960; deFremery and Pool, 1960; Cook and Langsworth, 1966a; Cassens and Newbold, 1967). Lawrie (1968a) found that the rate of pH fall depended upon the temperature and was not the same in all muscles. Bendell (1960) illustrated with rabbit Psoas muscle that the lower the temperature in the range of 0-37° C, the more slowly the pH fell. This is also true with lamb Semitendenosis muscle in the temperature range from 40° to 0° C (Cook and Langsworth, 1966a). The lower the temperature is of beef Longissimus dorsi muscle (LD) from 43° to 7° C, the slower the decline in pH (Marsh, 1954). On the other hand, by examining the temperature range from 37° to 0° C on

Sternomandibularis muscle, it was observed that over the range 37° to 5° C, the lower the temperature, the slower the rate of pH decline; however, the rate of pH fall was shown in this same study to be more rapid at 1-5° C (Cassens and Newbold, 1967; Newbold and Scopes, 1967).

Physical Changes

In the live animal, muscle is pliable and elastic, but over several hours after death, the muscle gradually becomes firm and inextensible as rigor mortis sets in. As the muscle proceeds toward "complete" rigor mortis, tenderness of the muscle is reduced, and the degree of reduction is dependent upon the severity and extent of contraction. Marsh (1954) stated that the onset of rigor mortis coincided with the completeness of ATP breakdown. After ATP declined to a minimal value, toughening occurred. The association between ATP decline and muscle stiffening has been discussed in work by Erdos (1943) and Bate-Smith and Bendall (1947) on rabbit; Lawrie (1968a) on whale; Lawrie (1953) on horse; Marsh (1954) and Howard and Lawrie (1956, 1957) on beef; and Lawrie (1968a) on pig. DeFremery and Pool (1960) observed that rapid stiffening in chicken muscle did not begin until the ATP content of the muscle reached about 30% of its initial concentration. The factors which influence the rate of disappearance of ATP also influence the time required for post-mortem stiffening to occur. In addition to stiffening, unrestrained muscle which contains ATP shortens during the development of rigor mortis. Shortening can occur only while ATP

is present; therefore, muscle is fixed in whatever state of contraction it is when all available ATP is utilized.

Infante and Davies (1962) observed that the onset of shortening in rigor mortis 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. The ATP-ase activity continued to rapidly deplete the ATP content in the muscle fiber, and no more was being produced. As ATP disappeared, 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.

Studies by Marsh and Leet (1966) and Davey et al. (1967) showed that ox Sternomendibularis muscle shortened during early post-mortem periods and this had an effect on the meat tenderness to a measurable degree. The researchers stated that muscles that shortened up to 20% in length caused little or no toughening; however, from 20% to 40% shortening, the toughness increased several fold. Beyond 40%, the meat became rapidly more tender, and at 60% shortening it was sheared as easily as meat in which almost no shortening had occurred. McCrae et al. (1971) showed a relationship between post-mortem shortening and tenderness for several ovine muscles on carcasses held at 18° C for varying delayed freezing periods. The relationship of shortening to tenderness closely resembled that observed by Marsh and Leet (1966). A study by Cook and Langsworth (1966a)

noted that minimum shortening of unfrozen ovine muscle occurred at temperatures between 5° and 20° C. Later, Cook and Langsworth (1966b) found that ovine LD had lower shear force values with increased incubation temperatures from 0° to 10° C. Shear force values from muscle incubated from 15-30° C remained constant.

In 1960 Locker reported that ox muscles went into rigor in widely differing states of contraction. He found the relaxed muscles to be more tender than the partially contracted muscles. He also found that if a Psoas muscle was excised at death and allowed to shorten, the meat would be less tender. Locker concluded that there was a relationship between post-mortem shortening and tenderness. In addition, Locker (1960) suggested that a relationship existed between the post rigor sarcomere length of the muscle and its ultimate tenderness.

In further work with sarcomere length and tenderness, Herring et al. (1965a) noted that sarcomere lengths of excised Semitendenosis and Psoas major muscles were associated with tenderness. Herring et al. (1965b) noted that sarcomere lengths were due to stretching which resulted from vertical suspension. If tension on the muscle was released, the length of the sarcomere shortened. It was demonstrated that as the sarcomere length increased, there was a decrease in fiber diameter, a decrease in shear force, and an increase in tenderness. Conversely, when the muscles shortened, there were corresponding decreases in sarcomere length, increases in fiber diameter, and decreases in tenderness. Differences in both fiber diameter and

sarcomere length were reported to be highly related to differences in tenderness.

Sink et al. (1965) found a close correlation between the mean sarcomere length in porcine LD and the duration of the delay phase of rigor. The study demonstrated that the amount of contraction may be related to post-mortem changes in muscle. The data illustrated that the shortening which occurred during the onset of rigor mortis was quite severe when the delay phase was of short duration, but as the duration of the delay phase increased, sarcomere shortening decreased. Sink concluded that the amount of sarcomere shortening was highly dependent upon the time course of rigor mortis.

Herring et al. (1966) noted the relationship between sarcomere length and tenderness. Shear force was found to increase linearly with increased fiber diameter and curvilinearly with decreased sarcomere length. A curvilinear relation also existed between fiber diameter and sarcomere length. Gothard et al. (1966) noted a similar relationship between bovine muscle sarcomere length and tenderness. They also noted that many of their samples excised soon after stunning contracted greatly upon cutting; however, as rigor mortis approached, the muscles lost their irritability, and very little response to cutting occurred after three hours post-mortem.

Temperature influences the extent and severity of rigor mortis, muscle shortening, and, ultimately, tenderness. Wilson et al. (1960) found the shortening of beef muscle to be much greater at 0-15^{o} 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 elevated temperature. Locker and Haygard (1963) found that isolated fresh Sternomandibularis muscle shortened more from 0-2° C than at 37° C and that minimum shortening occurred from 4-19° C. At temperatures greater than this range, shortening coincided with the onset phase of rigor mortis, but at lower temperatures, shortening began almost immediately. 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).

In 1967 Stromer and Goll experimented with bovine Semitendenosis (ST) muscles which were sampled immediately after death and at 24 hours with storage at 2°, 16°, and 37° C. Bovine muscle was supercontracted after 24 hours storage at 2° C, but was only slightly contracted after storage at 16° C for 24 hours. The ST held for 24 hours at 37° C was slightly less supercontracted than the 2° C muscle. Furthermore, muscle stored at 16° C for 24 hours showed only slight shortening. The study demonstrated that shortening at 2° C began within three hours after death, and at 37° C shortening began after five to eight hours.

Galloway and Goll (1967) investigated tension and shortening of porcine muscle strips immediately after death and again after eight hours post-mortem at 2°, 16°, 25° and 37° C. The muscle strips

shortened or developed tension at all post-mortem storage temperatures; however, shortening was maximal at 2° and 37° C and minimal at 16° C. The shortening occurred much sooner after death at 2° C than at all other temperatures. Similar findings were discussed by Busch et al. (1967).

In view of these studies dealing with the chemical and physical changes occurring in muscle post-mortem, it has been shown that the development of rigor mortis and consequent shortening is of practical significance in contributing to meat toughness. It is clearly desirable to minimize or prevent this toughness from occurring. This can possibly be accomplished by new chilling methods which allow rigor mortis to develop at a temperature at which post-mortem shortening is at a minimum.

"Hot" Processing

One of the earliest articles discussing the excision of muscle soon after slaughter was by Ramsbottom and Strandine in 1949. They investigated the effect on quality of beef boned before chilling. They showed that a faster rate of muscle chilling was achieved when the carcass was boned at one hour following death. There was as much as 15° F difference in temperature two hours post-mortem. The effect on tenderness of boning beef before chilling was estimated by cutting steaks from the LD at three, six, nine, and twelve days post-mortem and broiling them. Muscles which were excised prior to chilling were

less tender than those that remained on the carcass until chilled.

Reddy (1962) reported that bovine muscle exhibited a decrease in tenderness in the Semitendenosis muscle processed pre-rigor, but the Gluteus medius and Longissimus did not show any change. Trautman (1964) found that pork muscle processed pre-rigor had a greater emulsifying capacity and more salt-soluble proteins than post-rigor muscle.

Pulliam and Kelly (1965) found "hot" processed hams to have higher bacterial counts than conventionally processed pork. However, Barbe et al. (1966) and Barbe and Henrickson (1967) found less bacterial contamination in "hot" processed ham and hypothesized that the more rapid processing of the 'hot" hams as compared to conventional processing presented less opportunity for undesirable bacterial growth to occur. Mandigo and Henrickson (1966) evaluated the yield, tenderness, juiciness, flavor, and moisture content of "hot" processed hams (cured and smoked prior to chilling) and found them to be equal or superior to conventionally processed hams. Ham muscles excised hot, cured, and canned exhibited less free fluids in the can, a higher moisture content, greater shear values, more nitrosopigments, and more extensive cure diffusion than cold processed ham muscles (Reddy and Henrickson, 1969).

In 1968 Henrickson evaluated 'hot" processed pork for tenderness and fiber kinkiness. No evidence was found to discriminate against 'hot" processing. It was noted that 'hot" processed pork muscle was darker than conventionally chilled muscle. The difference disappeared

after chilling. As with pork, pre-rigor processed beef chuck showed a greater emulsifying capacity than did the post-rigor beef according to Acton and Saffle (1969).

Schmidt and Gilbert (1970) examined the tenderness of pre-rigor excised bovine muscles. At approximately two hours post-mortem the muscles from one side were excised, placed in gas impermeable bags, aged for 24 or 48 hours at 15° C, and then frozen at -14° C. The remaining side served as the control, and the muscles were left on the carcass and chilled at 9° C for 24 hours. The "hot" processed BF and LD muscles aged for 24 hours were shown to be similar to the controls in tenderness, while "hot" muscles aged for 48 hours were significantly more tender than muscles from the control side. There appeared to be no treatment effect on the SM, whereas the ST toughened. Bacterial counts were kept within the range of 10^2 to 10^5 / cm^2 of muscle surface after 48 hours storage at 15° C in the gas impermeable bags. It was concluded that pre-rigor excision of bovine muscle could produce an organoleptically and microbiologically acceptable product.

Brasington and Hammons (1971) indicated that "hot" processed beef carcass was economically favorable. On-the-rail boning would result in lower labor costs due to the use of semi-skilled workers during part of the operation. Also, higher yields were indicated along with a more flexible, sanitary, and less tiring operation for the workers.

Kastner (1972) studied the effects of excising bovine muscles at two, five, and eight hours post-mortem. The corresponding sides

were chilled for 48 hours at 2° C. The methods were compared for percent loss (shrink), shear force, color value, flavor, cooking loss, water binding capacity, percent moisture, and fat. No significant differences were found in shrinkage between the two processes at the two-hour holding period, but at five and eight hours the "hot" boned side had a smaller average percent loss. The two- and five-hour "hot" boned steaks from the LD muscle were less tender than the control steaks; however, no difference was found between the eight-hour treatments. The "hot" boned steaks evaluated for color and pressed fluid ratios were found to be statistically different from their controls at all three holding periods. In a test for percent cooking loss, no significant difference was found to exist between any of the holding periods and their corresponding controls. There was also no difference detected in flavor between the two-, five-, and eight-hour holding periods versus the 48-hour controls. It was concluded that "hot" boning was feasible when the muscles were excised at five or eight hours post-mortem.

Marsh et al. (1972) concluded that pork muscle excision pre-rigor followed by fairly rapid cooling (exposed muscles to 0° C within 20 minutes post-mortem) caused a significant toughening.

"Hot" processing bovine carcasses was evaluated by Schmidt and Keman (1974). The right side of each of six carcasses was excised one hour post-mortem, and the boneless wholesale cuts were kept at 2° C for four hours, after which they were placed in a 1° C room overnight.

They were chilled for seven days at 7° C. The left sides remained intact overnight at 1° C and were boned after seven days at 7° C. Taste panels and Warner-Bratzler Shear evaluation indicated no significant difference between the two processing treatments. Measurements of fiber diameter showed that most "hot" boned muscles increased in fiber diameter compared with the control.

Will (1974) and Will and Henrickson (1976) examined differences among shear force and penetration values between chilled and delay-chilled treatments of bovine carcasses excised at three, five, and seven hours post-mortem. They concluded that no major quality differences attributed to meat tenderness existed between beef fabricated 48 hours post-mortem at 1.1° C and that held three, five, or seven hours post-mortem at 16° C. Detectable variations registered by the trained tenderness taste panel were small between the two studies. All the findings indicated that the boning of beef as early as three hours post-mortem before chilling provides beef of satisfactory tenderness.

Kastner and Russell (1975) excised bovine muscles at six, eight, and ten hours post-mortem at 16° C. They examined shear force, rate of pH decline, color, and flavor of the resulting meat. Contrary to Will and Henrickson (1976), they found that a conditioning period of eight hours yielded a product of comparable quality to conventionally processed beef.

The eating quality of "hot" processed beef was evaluated by

Dransfield et al. (1976). Muscles excised three hours post-mortem were examined by a taste panel and consumer evaluation group to detect differences in tenderness, juiciness, flavor, and overall acceptability. Both groups indicated that no significant differences were found between the "hot" boned beef and the control. Consumers rated the overall acceptability of "hot" boned beef equal to that of conventionally processed beef for all cuts studied, except the flank, where the "hot" boned beef was preferred.

Electrical Stimulation

A process for electrical stimulation to improve the tenderness in meat was patented by Harsham and Deatherage (1951). They indicated that electrical irritation released the latent energy stored within the muscle and rendered it more susceptible to enzymatic digestion which produced a more tender product. Also, the rate of pH decline was accelerated in the electrically stimulated muscle.

DeFremery and Pool (1960) electrically stimulated chicken muscle to exhaustion and found a faster rate of pH decline and an accelerated post-mortem disappearance of ATP. The shear values of the stimulated muscles were higher than those of the unstimulated controls.

Karpatkin et al. (1964) studied the effect of electrical stimulation on the rate of glycolysis in frog Sartorius muscle. The rate of glycolysis as measured by lactate formation increased with the number of shocks administered per minute, when shocks of 15 volts and two

milliseconds duration were used. The rate of pH decline in muscles of stimulated pigs also increased, according to Hallund and Bendall (1965). Forrest et al. (1966) and Forrest and Briskey (1967) indicated that muscles from pigs which exhibited a slow rate of post-mortem glycolysis responded more to electrical stimulation than those with an intermediate rate.

Carse (1973) reported that a brief period of electrical stimulation of freshly slaughtered lamb carcasses by 250-volt pulses tended to increase subsequent rates of post-mortem glycolysis and hasten rigor onset. Stimulated carcasses put into a blast freezer at five hours post-mortem were as tender as untreated carcasses held for 16 hours before freezing. Pulse voltage was related to the degree of acceleration of post-mortem glycolysis.

Chrystall and Hagyard (1975) investigated the use of electrical stimulation as a process for acceleration of conditioning and tenderness in lamb carcasses. The success of trials involving stimulation, either pre- or post-dressing, were variable. Pre-dressing stimulation, although more difficult, resulted in better tenderness. Stimulation of the dressed carcass was effective if freezing the carcass was delayed. Electrical stimulation of normally shackled carcasses immediately after slaughter provided highly significant improvement in tenderness of early frozen lambs (Chrystall et al., 1975). Chalcroft and Chrystall (1975) measured the distribution pattern of current flow in lamb carcasses during electrical stimulation. They found that

unless both hind legs were connected together the current would only flow between the neck electrode and one leg. Devine et al. (1975) reported that electrical stimulation reduced conditioning time for lamb from approximately 16 hours to about one hour. They concluded that the attendant advantages in reduced handling and spoilage, and in time-saving and space, make the concept of such hastened conditioning a most attractive processing possibility.

Chrystall and Hagyard (1975) used high voltage electrical stimulation to accelerate post-mortem glycolysis in lamb carcasses. When the authors compared stimulated frozen lambs to unstimulated frozen lambs at 60 minutes post-mortem, they found that shear values for the stimulated were about half the values obtained for the others. In a similar experiment involving electrically stimulated beef carcasses, Davey et al. (1976) reported increased tenderness in the Longissimus dorsi muscle. Stimulated and unstimulated sides were placed in a chill cooler at 40 minutes post-mortem and boned after 24 hours.

Bendall et al. (1976) electrically stimulated beef carcasses shortly after slaughter at varying voltage, pulse frequency, and duration, with the aim of accelerating the fall of pH, destruction of ATP, and onset of rigor in the muscles, so that the meat could be chilled rapidly after slaughter without danger of cold shortening. The results showed that voltages of about 700, with the current applied for at least two minutes, with a frequency of 25Hz applied immediately after slaughter or in a dressed state 50-60 minutes later was very effective in rapidly

lowering the ATP level and pH of the major muscles. The fall in pH from 6.3 to 5.7 in the stimulated sides was more than four-fifths faster in time than in the unstimulated sides. The muscles of stimulated carcasses showed no deleterious effects of stimulation. The observed drip loss from the hind-limb jointed six days after slaughter was not significatnly greater than that from unstimulated carcasses.

Tang (1977) studied the effect of post-mortem electrical stimulation on the myoglobin derivatives of bovine muscles. He reported that total pigment and total myoglobin concentrations were not affected by stimulation, but there was an increase in oxymyoglobin content in the electrically stimulated samples. Visual appraisal indicated the stimulated samples to be bright red in color, while the control samples were dark purplish red.

CHAPTER III

MATERIALS AND METHODS

Twelve Hereford steers and heifers of approximately the same grade (choice) ranging in weight from 309 to 406 Kg with a mean weight of 359±10 Kg were utilized in this study. Each animal was delivered to the Meat Science abattior 24 hours prior to slaughter. The first six animals were used in Experiment 1 and the remaining six in Experiment 2. Following the 24-hour shrinkage period, the live weight of the animal was taken and recorded. Care was exercised in handling the animals to avoid any adverse effect upon post-mortem metabolic reactions, as well as ultimate product quality. Each animal was stunned with a captive bolt percussion stunner, raised from the floor by both legs and bled. The time of death was recorded. The carcass was carefully washed to minimize bacterial contamination. The slaughter and dressing operations proceeded as rapidly as possible so that Federal Inspection was given within 30 minutes post-mortem. The sides were suspended from a rail via a roller and hook through the Achilles tendon. Following inspection of the split carcass, the hot weight of both the right and left sides was recorded. Both sides were immediately moved to a 16° C holding room. Either the

right or the left side of the carcass was randomly assigned to one of two treatments: 1) electrical stimulation or 2) no electrical stimulation (control). This was followed by a holding period and "hot" boning. The time factors involved in electrical stimulation, holding period, and "hot" boning varied between Experiment 1 and Experiment 2.

Experiment 1

At one hour post-mortem, the side to be stimulated was connected to a pulse generator via two leads. Lead one consisted of a teflon band (3/4" x 16") in which eight 3-inch stainless steel shroud pins were inserted. The pins were connected by copper wire. Lead one was inserted into the hindquarter shank muscles, principally the Gastrocnemius and distal Biceps femoris. Lead two consisted of three 3-inch stainless steel shroud pins connected by copper wire, which was inserted into holes drilled in the third, fourth, and fifth vertebrae.

The pulse generator delivered a direct current square wave pulse with a frequency of 400 cycles per second and a duration of .5 milliseconds. The voltage was increased to 300 volts maximum, as read from a Hewlett Packard model 120 AR oscilliscope. Electrical stimulation was initiated at one hour post-mortem and concluded after 30 minutes.

Upon cessation of stimulation, the leads were removed and the suspended side was held at 16° C until four hours post-mortem. The control side was suspended in the 16° C holding room for the same

four hours post-mortem as the treated side. Following the expiration of the holding period, each side was fabricated into a streamlined hindquarter.

Fabrication consisted of chuck removal at the fifth thoracic vertebrae with the flank and plate removed as in the commercial trade (Figure 1). The Supraspinatus (SS) muscle was removed from the chuck for further study. After the hindquarter was streamlined, on-the-rail dissection of muscles and muscle systems was initiated in the 16° C holding area. First, excess fat was carefully stripped from the muscle so that the epimysium remained intact on the muscle surface. The muscles from the streamlined hindquarter were removed in the following order: Tensor facia latae, Sartorius, Semimembranosis (SM), Semitendenosis (ST), Biceps femoris, Quadriceps complex (QC), Psoas major (PM), Gluteus complex (GM), and lastly the Longissimus dorsi (LD). The remaining lean and small muscles were excised and utilized for lean trim. As soon as the excision of the SS, SM, ST, QC, PM, GM, and LD was completed, any excess far remaining on the muscle was trimmed off. Each muscle was then labeled and wrapped with a saran film to reduce desiccation. The other components (bone, fat, lean trim, chuck, and unutilized muscles) were placed in a 1.1° C cooler and processed at a later time. These components were not utilized in this study. The dissection of the streamlined hindquarter was completed approximately one hour after initiation. The wrapped

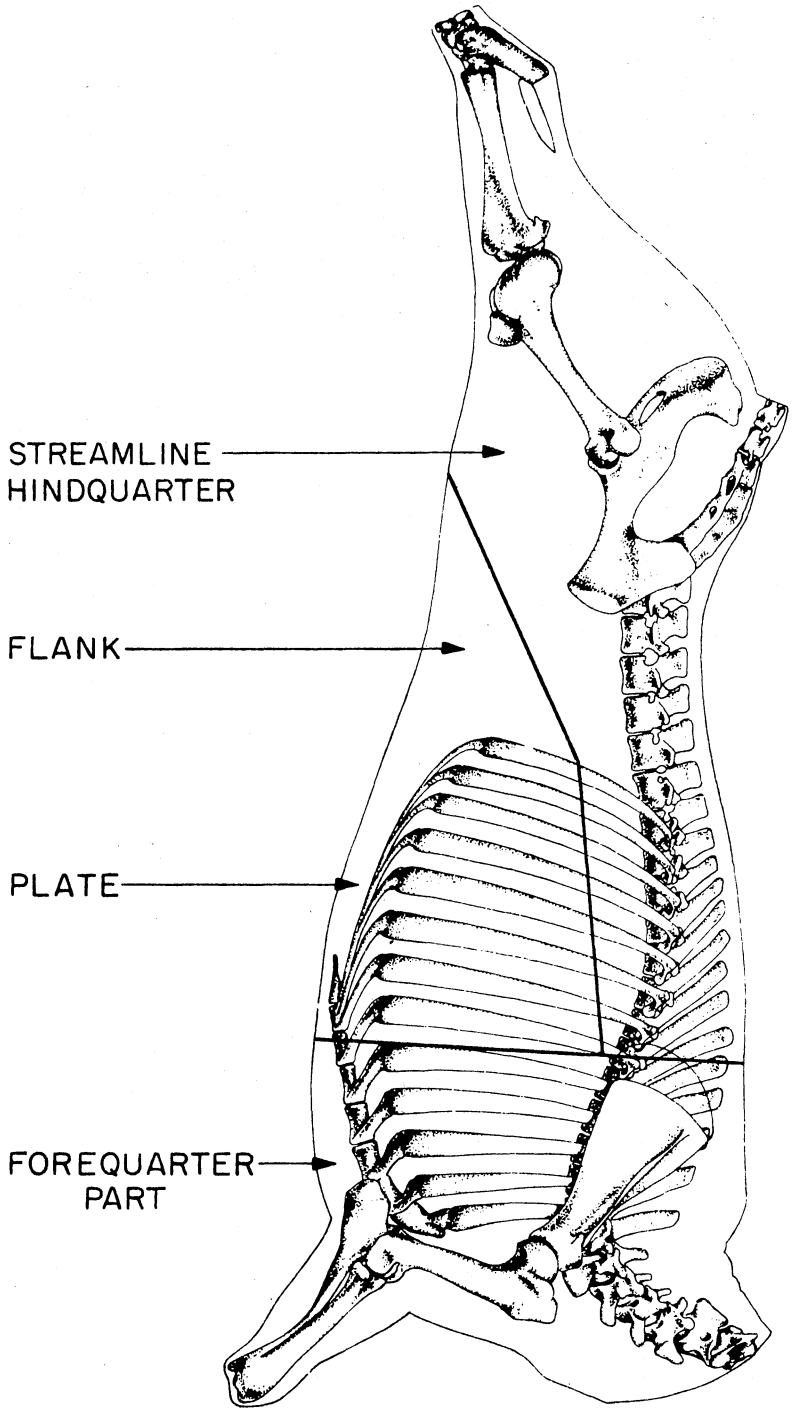

Figure 1. Diagram of Carcass Preparation for "Hot" Boning

muscles were then transferred to a 1.1° C cooler for the remaining portion of a 48-hour chilling period.

Experiment 2

At thirty (30) minutes post-mortem, the side to be stimulated was connected to the same pulse generator as was used in Experiment 1. The same leads were used and were inserted into the carcass side in an identical manner to the first experiment.

The pulse generator delivered a direct current square wave pulse with a 400-cycles-per-second frequency and .5 millisecond duration. Three hundred (300) volts was the unit maximum. Electrical stimulation was initiated 30 minutes post-mortem and concluded after 15 minutes.

Upon cessation of stimulation, the suspended side was held at 16° C until two hours post-mortem. The control side was suspended in the 16° C holding room for the same two hours post-mortem as the treated side. Following the expiration of the holding period, each side was fabricated into a streamlined hindquarter in an identical manner as that described under Experiment 1.

The same muscles that were utilized in Experiment 1 (SS, SM, ST, QC, PM, GM, LD) were excised and utilized in Experiment 2. These muscles were also wrapped in saran film and transferred to a 1.1° C cooler for the remaining portion of a 48-hour chilling period.

Sampling for Shear Force Determination and Organoleptic Evaluation

At the expiration of the 48-hour post-mortem chilling period, all muscles were taken from the cooler to the cutting room for removal of steaks for tenderness evaluation by both objective (shear force) and subjective measures (organoleptic). The muscles were cut into 3.81 cm steaks, following the schematic plan presented in Figure 2, in order to compare both the stimulated and control samples. Steaks for the shear force determination were taken from all seven muscles (SS, SM, ST, QC, PM, GM, LD). Steaks for the organoleptic evaluation were taken only from LD and QC muscles in Experiment 2. All steaks were packages, labeled, and frozen (-10° C) for analysis at a later date.

Shear Force

The steaks from the SS, SM, ST, QC, PM, GM, and LD muscles, as sketched in Figure 2, were thawed at 1.1° C for 24 hours. Two steaks from each of the seven test muscles were evaluated; thus 28 steaks were analyzed from each of the 12 carcasses. Each thawed steak was labeled with a small metal pin and tag with number for identification. The steaks were towel dried and weighed. Each group of four steaks from the same muscle (2 control and 2 stimulated) were placed together in an aluminum tray and cooked in a Boldgett

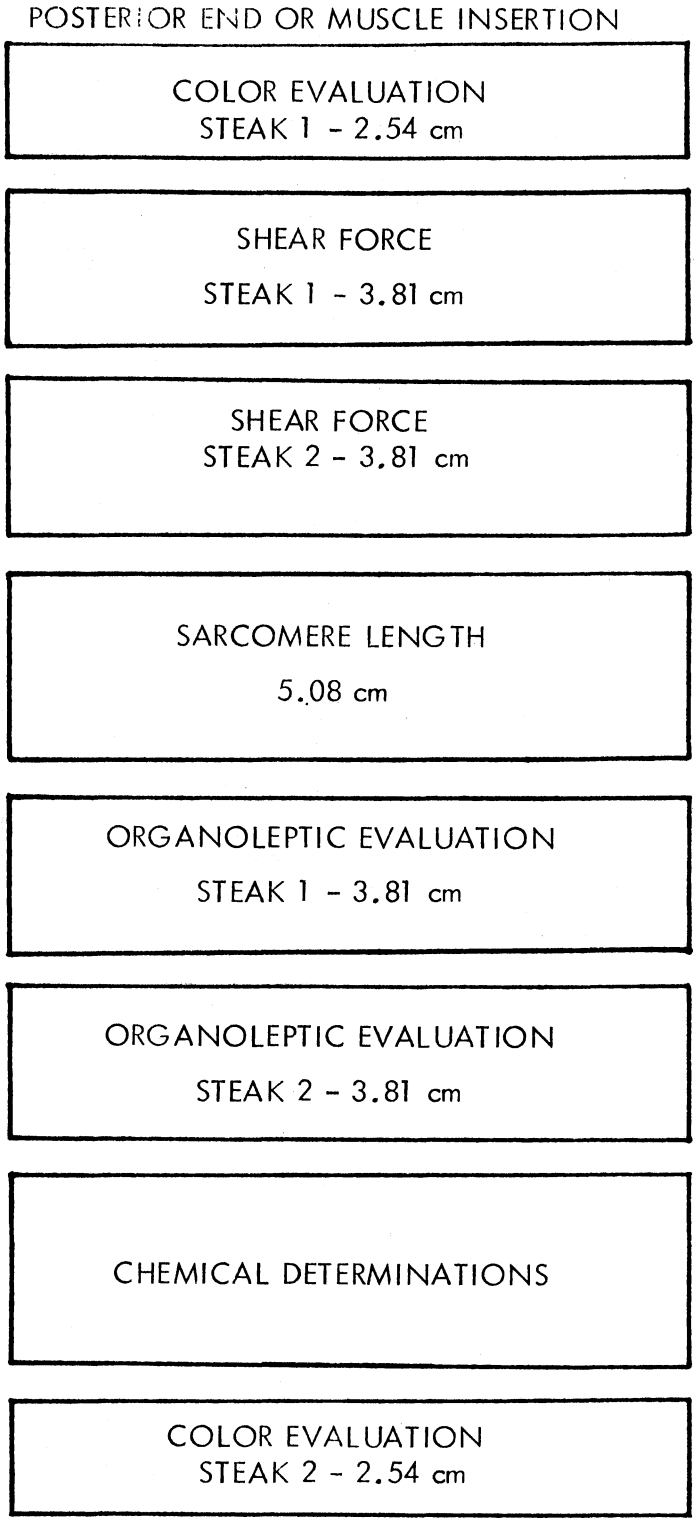

Figure 2. Schedule for Removing Steaks for Quality Determinations on Test Muscles

convection oven set at 142° C until an internal meat temperature of 73° C was reached. Premium Instrument meat thermometers were inserted into the geometric center of the uncooked steaks to insure uniformity of internal doneness. When the desired internal temperature was reached, the steaks were removed from the oven, blotted, and allowed to cool approximately 15 minutes. The steaks were then weighed again.

The cooked steaks were cooled for about 45 minutes and then wrapped (to prevent excess moisture loss), and chilled for 24 hours at 1.1° C to provide adequate firmness to insure uniform cores (Kastner and Henrickson, 1969).

From each steak, five 1.27 cm diameter cores (Falk, 1974) were taken by a mechanical boring device (Kastner et al., 1973). Each core was analyzed twice by a Warner-Bratzler Shear instrument, providing a total of 10 shear force readings per steak.

Organoleptic Evaluation (Tenderness Panel)

The LD and QC muscles from Experiment 2 were appraised by a trained tenderness panel. The panel consisted of six members, both men and women, of different ages selected from the employees of the Meat Science Laboratory. The panelists participated in five training sessions to familiarize them with test procedures and were given a wide variety of differing degrees of meat tenderness to test their ability to discriminate.

The duo-trio test (Kramer and Twigg, 1966; Amerine et al., 1965)

was used to determine whether differences in tenderness existed between treatments. The test was organized such that one of the samples served as the reference and the remaining two samples were unknown. Each panelist was asked to choose which of the unknowns best matched the reference sample. As may be noted from Figure 2, two sample steaks from each muscle were available for each treatment side. /Steak 1 from both treatments or steak 2 from the same two treatments was evaluated at a given setting. The order of presentation of steak 1 or steak 2 to the panel was determined by a toss of a coin. After randomizing the evaluation order, a second coin toss was made to determine which treatment (control or stimulated) would serve as the pair (reference and corresponding unknown) and which would be designated as the single (odd) sample. The steaks were then cooked on racks in aluminum foil trays in a convection oven set at 142° C until an internal meat temperature of 73° C was reached. Upon attaining this internal temperature, the steaks were removed from the oven and blotted. A 1.27 cm diameter core device was used to remove twelve cores (2 per panelist) from the steak used for the pair samples and six cores (1 per panelist) from the steak used for the single sample. Steaks (steak 1, control and stimulated, for example) were carefully oriented so that the cores were removed from the same position up and down the steak for both the pair and single samples given a panelist. In the case of the single steak, each core was removed from a point midway between the position of the paired cores sampled on the

corresponding steak. Each core was placed in a 30 ml. plastic medicine vial which fitted into a wooden holder tray (Figure 3). As may be noted, three symbols were imprinted on the tray: $, &, !. The dollar sign always served as the reference, whereas the ampersand and exclamation point always were unknown. A coin toss was used to determine which of the two symbols representing the unknown samples would serve as the second member of the pair, matching the reference ($) sample, for each panel member. The randomizations, as discussed, were accomplished before each test session and recorded. After the sample vials were placed in the tray, they were covered with aluminum foil and placed into a warm electric oven and held at 50° C until evaluated. The oven was used to insure that the samples in each tray were at a uniform temperature when they were presented to the panelists. Scoring by the panel members was accomplished within 15 minutes after the samples were prepared, insuring reliable evaluation.

Upon receiving a tray with the three samples, each judge was asked to perform the duo-trio test first and then indicated a preference for one of the two unknowns. If there was no preference, the judge was to flip a coin. Lastly, each judge assigned each unknown a level of acceptability based on a six-point hedonic scale (the larger the number, the higher the level of acceptability). The judges were given sufficient privacy so that independent results were obtained. Care was taken to assure that the evaluation room was dimly illuminated with red light to avoid identification of the samples because of color

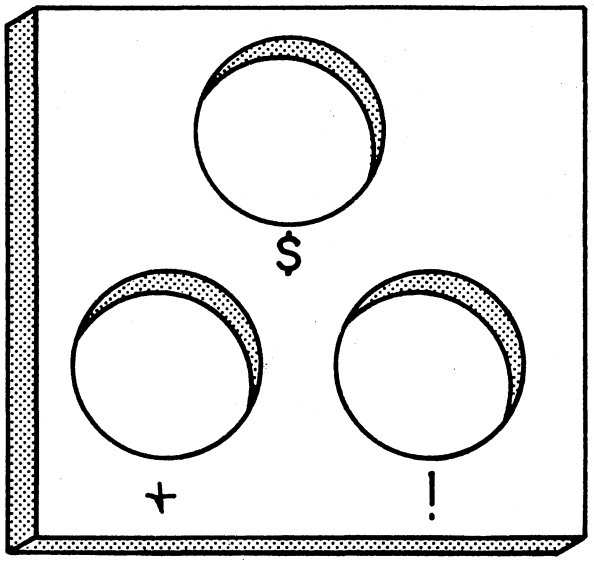

Figure 3. Sample Tray Used in the Duo-Trio Analysis

differences. To eliminate odors from the preparation room, a positive air pressure system was utilized.

The duo-trio panel responses were evaluated by means of Kramer and Twigg (1970) Table 85, such that 45 correct responses out of 72 were required for the attaining of significance at the 5% level. The preference between the two unknowns was analyzed by assigning the preferred treatment a value of two and the remaining treatment a value of one. Similar procedures in evaluating the hedonic scale rating were used, such that the treatment receiving the higher level of acceptability was ranked with a two and the remaining treatment assigned a value of one. In case the resulting response was a tie, each treatment received a value of 1.50.

Percent Cooking Loss

Pre- and post-cooked weights were taken on each of the steaks from both Experiments 1 and 2 that were used for shear measurements, as was previously discussed, in order to compare the difference in percent cooking loss between the stimulated and control. The formula for calculating percent cooking loss was:

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

A = Raw Steak Weight
B = Cooked Steak Weight

TENDERNESS EVALUATION

Name_____

Product_____

Date_____

Two of the three samples are identical. Please circle the pair samples, then check a preference for either the pair or the single sample.

Circle the duplicate samples:

$ & !

Check your preference:

☐ Pair Sample ☐ Single Sample

Rate for tenderness only. Circle the appropriate level of acceptability for the pair and the single sample.

Pair Sample	Single Sample
(1) Highly Unacceptable	(1) Highly Unacceptable
(2) Unacceptable	(2) Unacceptable
(3) Slightly Unacceptable	(3) Slightly Unacceptable
(4) Slightly Acceptable	(4) Slightly Acceptable
(5) Acceptable	(5) Acceptable
(6) Highly Acceptable	(6) Highly Acceptable

Comments:

Figure 4. Taste Panel Evaluation Sheet

Statistical Analysis

The SAS computer programming system (Service, 1972) was used to analyze all data presented in this study. Organoleptic panels were evaluated by using the ranking procedure described by Conover (1971) in conjunction with the Chi-square test. The Analysis of Variance was used in the remainder of the statistical evaluations. F-tests concerned with the main unit analysis utilized the animal x stimulation mean square with five degrees of freedom as the error term. The statistical analysis is presented in the Appendix (Table VI) showing the Analysis of Variance for Warner-Bratzler Shear data. It is important to note that each experiment was considered as a separate test. Thus, no statistical comparison was made between Experiment 1 and Experiment 2.

CHAPTER IV

RESULTS AND DISCUSSION

Shear Force Evaluation

Shear force values, as measured by the Warner-Bratzler Shear, indicated, in Experiment 1 (4-hour boning, 60-minute holding, 30-minute stimulation), that there was no significant difference ($P > .05$) between the stimulated and control samples (1.27 cm cores) from the GM, PM, QC, SM, and SS muscles. (Table I and Figure 5.) The stimulated steak samples from the GM, QC, and SM were slightly more tender than the control samples, whereas the PM and SS stimulated muscles appeared to be slightly less tender than the control. Shear force values for the LD and ST muscles showed a significant difference ($P < .05$) between the stimulated and control steaks. The difference indicated that the electrically stimulated LD and ST steak samples were more tender than the corresponding nonstimulated samples. These differences have little practical importance, however, since Will (1974) stated that boning of beef muscle three hours post-mortem before chill provided beef of satisfactory tenderness. The muscles used in Experiment 1 were excised four hours post-mortem, and therefore the control muscles should have been satisfactory in

TABLE I

MEAN SHEAR FORCE VALUES OF MUSCLES
AS INFLUENCED BY STIMULATION

Muscle[a]	Experiment	Shear Force	
		"Control"	"Stimulated"
		Kg.	Kg.
GM	1[b]	4.36	4.26
	2[c]	5.17	4.79
LD	1	5.18	3.71 *
	2	7.05	4.78 *
PM	1	2.69	2.83
	2	3.67	3.66
QC	1	4.51	4.21
	2	6.01	5.40
SM	1	5.23	5.13
	2	7.19	6.30 *
SS	1	4.63	5.01
	2	7.58	6.18 *
ST	1	5.38	5.13 *
	2	7.68	6.48 *

[a]Muscle - Gluteus medius, Longissimus dorsi, Psoas major, Quadriceps complex, Semimembranosis, Supraspinatus, Semitendenosis.
[b]Post-mortem 4-hour boning, 60-minute holding, 30-minute stimulation (Experiment 1).
[c]Post-mortem 2-hour boning, 30-minute holding, 15-minute stimulation (Experiment 2).
* = Significant difference ($P < .05$) between "stimulated" and "control" steaks.

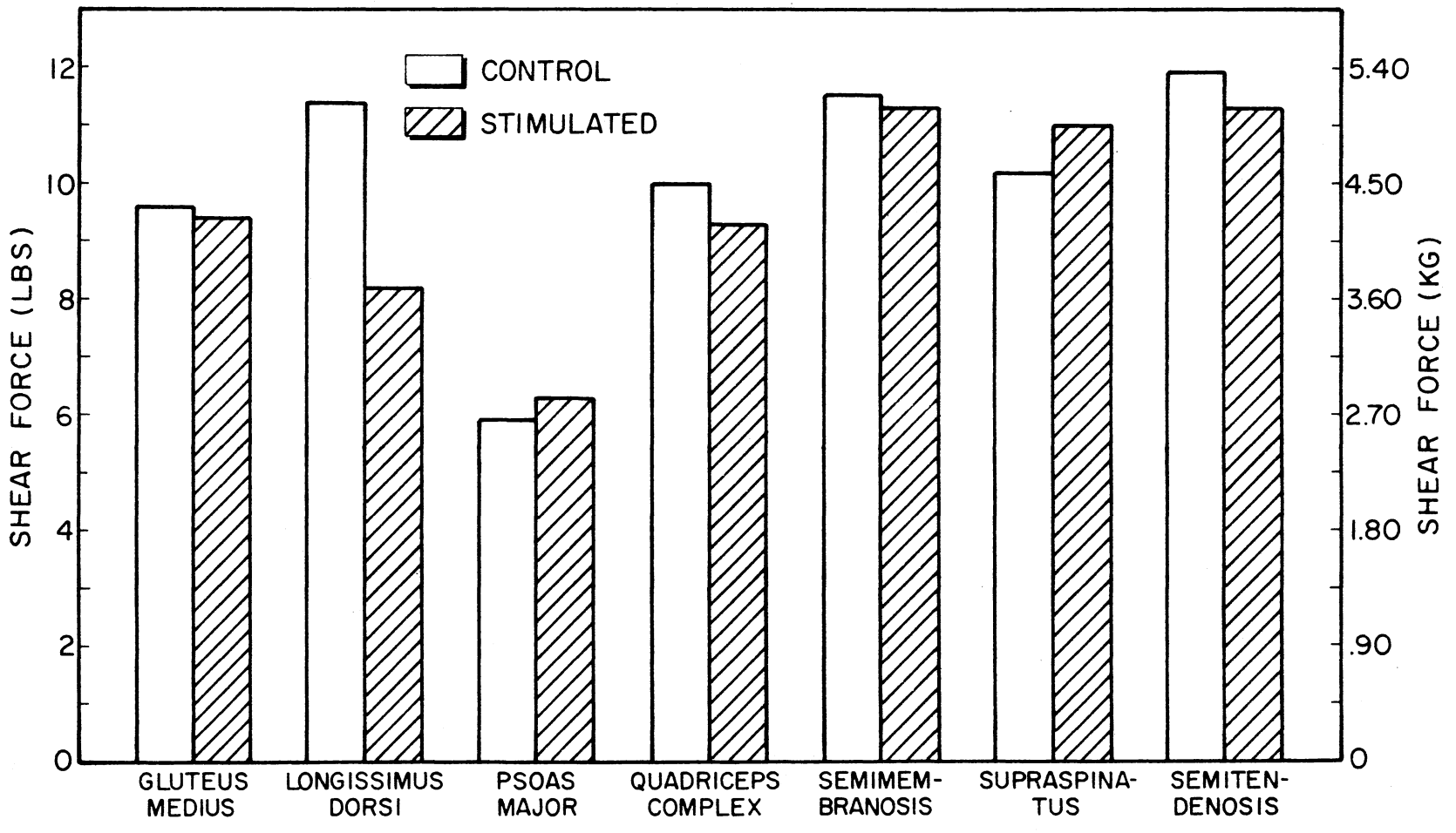

Figure 5. Tenderness Evaluation of Muscles Boned at 4 Hours and Stimulated for 30 Minutes (Experiment 1)

tenderness without stimulation.

The shear data for measuring muscle tenderness, Experiment 2 (2-hour boning, 30-minute holding, 15-minute stimulation) is shown in Table I and in Figure 6. The GM and QC stimulated steak samples required slightly fewer Kilograms of shear force than the corresponding control steaks, but the difference was not significant ($P > .05$). The shear force values of the PM stimulated and nonstimulated steak samples were identical, indicating that the tenderness was equal for both processes. Shear force differences between stimulated and control steak samples were significant ($P < .05$) in the LD, SM, SS and ST muscles. The stimulated steaks were more tender than the corresponding unstimulated muscles. Kastner (1972) indicated that muscles excised "hot" two hours post-mortem experienced a significant reduction in tenderness, compared to conventionally processed beef. The muscles used in Experiment 2 were excised two hours post-mortem, and it appeared that electrical stimulation, for the most part, alleviated the problem of reduced tenderness in muscles excised prior to three hours post-mortem.

It should be noted that the difference in mean shear force in stimulated and control steaks was greatest in the LD muscle in both Experiments 1 and 2. The difference in mean shear force in Experiment 1 was 1.47 Kilograms, and in Experiment 2, 2.27 Kilograms. The next closest muscle was the SS, with 1.40 Kilograms of difference between the control and stimulated, in Experiment 2. The wide difference in

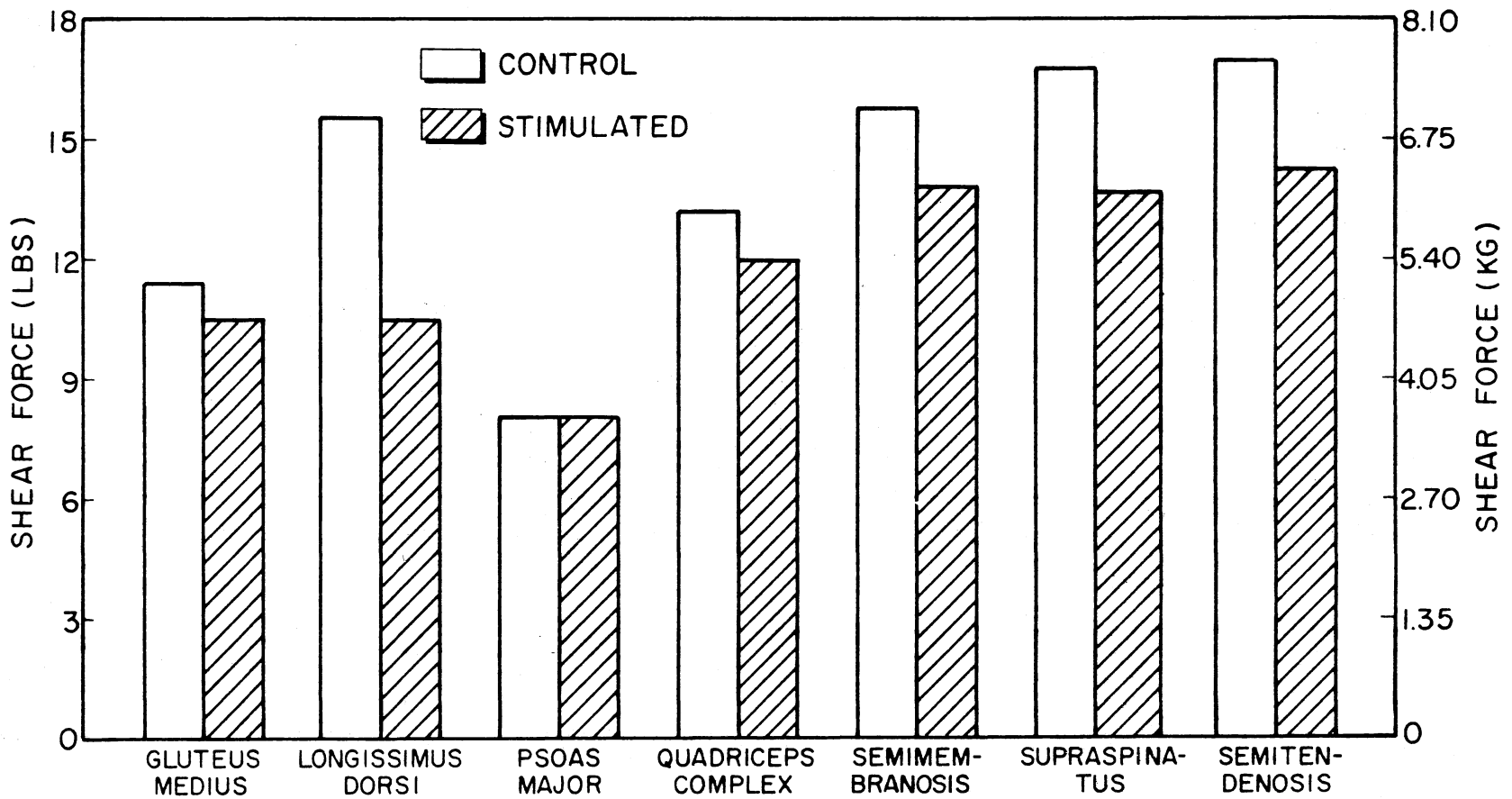

Figure 6. Tenderness Evaluation of Muscles Boned at 2 Hours and Stimulated for 15 Minutes (Experiment 2)

shear force in the LD muscle could be due to the nearness of the muscle to the flow of electric current. Since one electrode was inserted in the cervical vertebrae and the second electrode in the hindquarter shank muscles, it would be expected that the electric current would flow down the vertebral column. The Longissimus dorsi (LD) was the nearest muscle to the vertebral column of those examined. It would, therefore, be expected that the LD would have been more affected by the flow of electrical current.

Evaluation by Taste Panel

The LD and QC muscles, from Experiment 2 only, were used for taste panel evaluation. Muscles from Experiment 1 were not used, since muscles boned three hours or more post-mortem have been indicated to be acceptable by taste panelists (Will, 1974).

A review of Table 85 as shown in Kramer and Twigg (1970) revealed that 45 correct duo-trio pairings out of 72 possible were required to achieve a significant difference at the five percent level. As shown in Table II, this criterion was met for both muscles examined. This indicated that the judges could distinguish differences in tenderness between stimulated and control steaks from both the QC and LD muscles. It appeared that the judges found it easier to detect a difference in the LD (56 out of 72 correct) than in the QC (45 out of 72). The apparent ease in identifying matching LD control and stimulated samples is supported by the data from the Warner-Bratzler Shear

TABLE II

PAIRED COMPARISON ANALYSIS

Muscle	Total Number of Paired Comparisons	Total Number Identifying Pair
Quadriceps complex	72	45 *
Longissimus dorsi	72	56 *

* = Significant difference ($P < .05$) between stimulated and unstimulated steaks.

TABLE III

PREFERENCE RANK[a] ANALYSIS

Muscle	Total Number of Preference Comparisons	[b]Mean Rank of Unstimulated Steaks	[b]Mean Rank of Stimulated Steaks
Quadriceps complex	72	1.31	1.69 *
Longissimus dorsi	72	1.10	1.90 *

[a]Range from 1.0 to 2.0

[b]Larger value denotes increased preference

* = Significant difference ($P < .05$) between stimulated and unstimulated steaks

force values. The difference in mean shear force was greater for the LD muscle (2.27 Kilograms) as compared to the QC muscle (.61 Kilograms). (Table I)

Analysis of the preference ranking indicated that the judges preferred the stimulated QC and LD samples a greater number of times ($P<.05$) than nonstimulated samples (Table III). With a preference rank of 2 equalled most preferred and 1 equalled least preferred, the QC was ranked 1.69 for the stimulated and 1.31 for the control. The LD ranked 1.90 for the stimulated and 1.10 for the control. The high preference score for the stimulated LD samples related well to the low tenderness score (as measured by shear force) for the stimulated muscles versus the high shear force value for the control (Table I).

Rank analysis of the ranked hedonic scale scores revealed that the judges assigned the tenderness of stimulated steak samples a higher level of acceptability (Table IV) than the nonstimulated samples, and the difference in frequency was significant ($P<.05$) for both the QC and the LD muscles. As may be observed in Figure 7, the Hedonic Scale scores were in the slightly acceptable category for both the stimulated QC and LD muscles. However, the control QC score fell into the slightly unacceptable category, and the control LD score was in the unacceptable category. This result followed closely the shear force data. The QC muscle had a mean shear force value of 6.01 Kilograms, and the LD value was 7.05 Kilograms (Table I).

TABLE IV

HEDONIC SCALE SCORE-RANK ANALYSIS

Muscle	Total Number of Hedonic Scale Comparisons	Mean Unstimulated Hedonic Score	Mean Stimulated Hedonic Score	Mean Unstimulated Ranked Score	Mean Stimulated Ranked Score
Quadriceps complex	72	3.79	4.28 *	1.39	1.65 *
Longissimus dorsi	72	2.74	4.51 *	1.17	1.83 *

[a]A score of 1 being highly unacceptable and a score of 6 highly acceptable.

[b]Larger value denotes higher acceptability.

* = Significant difference ($P < .05$) between stimulated and unstimulated steaks.

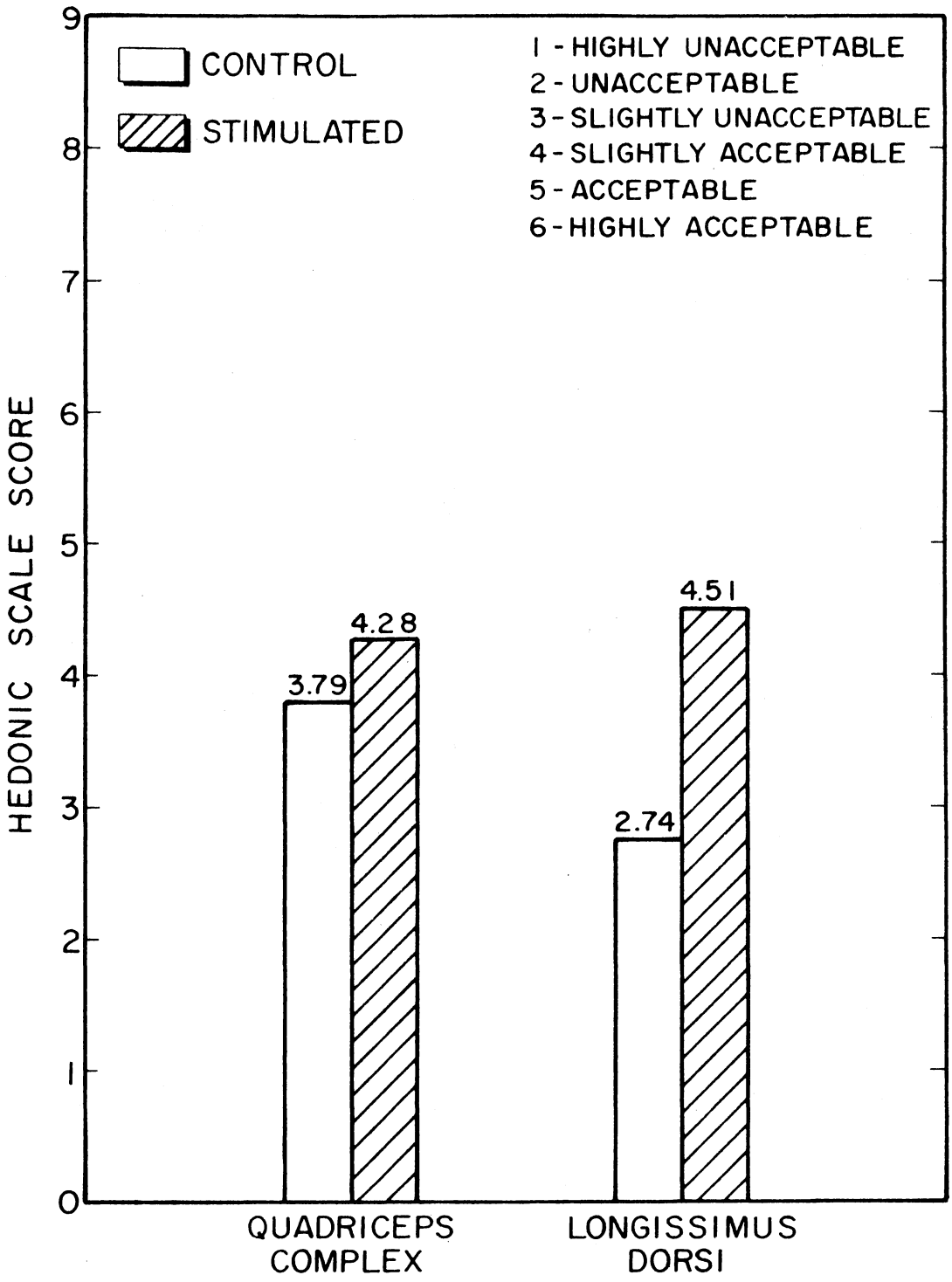

Figure 7. Subjective Measure of Tenderness as Influenced by Muscle and Stimulation

Percent Cooking Loss

Percent cooking loss was evaluated in order to determine if electrical stimulation would affect this factor. Falk (1974) reported no significant difference ($P > .05$) between "hot" and "cold" boned LD at either three-, five-, or seven-hour holding periods. Since "hot" boning would not cause an increase in percent cooking loss, it needed to be determined if stimulation would have an effect.

Evaluation of the percent cooking loss data presented in Table V shows that differences in moisture content of stimulated versus control steaks from all muscles in both Experiment 1 and Experiment 2, except for stimulated two-hour boned LD and ST steaks, were not statistically significant ($P > .05$). A possible cause for the increased percentage in the LD may be a decrease in water holding capacity. Falk (1974) found a slight decrease in the water holding capacity of "hot" boned LD.

TABLE V

PERCENT COOKING LOSS OF MUSCLES AS INFLUENCED BY STIMULATION

Muscle[a]	Experiment	"Control" Cook Loss (%)	"Stimulated" Cook Loss (%)
GM	1[b]	23.65	24.11
	2[c]	23.36	25.44
LD	1	22.43	23.11
	2	23.65	25.34 *
PM	1	23.59	23.74
	2	23.68	23.01
QC	1	26.10	28.07
	2	26.10	27.17
SM	1	28.59	27.40
	2	28.70	29.37
SS	1	31.32	28.19
	2	28.34	28.43
ST	1	23.47	21.33 *
	2	26.45	27.07

[a]Muscle - Gluteus medius, Longissimus dorsi, Psoas major, Quadriceps complex, Semimembranosis, Supraspinatus, Semitendenosis.

[b]Post-mortem 4-hour boning, 60-minute holding, 30-minute stimulation (Experiment 1).

[c]Post-mortem 2-hour boning, 30-minute holding, 15-minute stimulation (Experiment 2).

* = Significant difference ($P < .05$) between "stimulated" and "control" steaks.

CHAPTER V

SUMMARY AND CONCLUSIONS

Twelve Hereford steer and heifer carcasses were investigated to evaluate the effect of electrical stimulation and hot boning on various muscles. Six carcasses were used in each of two experiments. In Experiment 1, one side of each of six carcasses was subjected to a 60-minute holding period at 16° C, followed by 30 minutes of electrical stimulation of 300 volts with a frequency of 400 cycles per second and a duration of .5 milliseconds. This was followed by excision of the muscles at four hours post-mortem. The remaining side was held at 16° C until boned at four hours. In Experiment 2, one side was randomly assigned to be electrically stimulated 30 minutes post-mortem for 15 minutes, using the same voltage, frequency, and duration as in Experiment 1. Both sides were held at 16° C until the muscles were excised at two hours post-mortem. The Gluteus medius (GM), Longissimus dorsi (LD), Psoas major (PM), Quadriceps complex (QC), Semimembranosis (SM), Supraspinatus (SS), and Semitendenosis (ST) muscles were analyzed in the investigation, to evaluate tenderness as measured by the Warner-Bratzler Shear and a trained taste panel. Percent cooking loss was also determined.

Differences in shear force values between stimulated and nonstimulated treatments in Experiment 1 were small in all muscles except the LD, averaging less than 0.05 Kilograms. The shear force value of the LD was statistically significant ($P<.05$). In Experiment 2, the LD, SM, SS, and ST had shear force values that were significantly different ($P<.05$), and all stimulated muscles averaged 1.13 Kilograms less in shear force than their corresponding controls.

The trained taste panel detected variations in tenderness between the two treatments and found steaks from the stimulated muscles to be significantly ($P<.05$) preferred over the control steaks. The Duo-Trio test, Preference, and Hedonic Scale scores all supported findings indicated by the Warner-Bratzler Shear and percent cooking loss that electrical stimulation and boning of beef two hours post-mortem provides beef of acceptable tenderness.

Further research is now necessary to determine if electrical stimulation is feasible on a large scale. It would be desirable to stimulate the carcass as soon after death as possible and to excise the muscles even earlier than two hours post-mortem. Adaptations of these parameters needs further investigation. Also, research studies on the microbial, shelf-life and economics of processing should be initiated.

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TABLE VI

ANALYSIS OF VARIANCE OF WARNER-BRATZLER SHEAR DATA

	Experiment	Muscle	Source ANI	STIM	ANI*STIM	STK(ANI STIM)	TOTAL
DF	1 & 2	All	5	1	5	12	23
Mean Squares	1	GM	6.92	.31	1.66	2.77	3.32
		LD	.95	62.04	6.65	1.10	4.92
		PM	2.65	.57	.44	.30	.86
		QC	4.42	2.66	.94	3.50	3.11
		SM	8.68	.32	1.03	1.75	3.04
		SS	9.07	2.79	.48	2.57	3.47
		ST	5.77	1.79	.22	.91	1.85
	2	GM	2.47	4.09	2.85	1.21	1.97
		LD	6.74	150.45	11.48	2.03	11.56
		PM	6.80	.00	.47	.57	1.87
		QC	6.69	10.64	3.14	4.08	4.73
		SM	4.61	23.50	2.80	2.70	4.04
		SS	6.35	56.61	1.41	.96	4.65
		ST	5.02	41.98	.72	1.52	3.86

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