THE EFFECT OF HOT MUSCLE BONING ON LEAN YIELD, COOLER SPACE REQUIREMENTS, COOLING ENERGY REQUIREMENTS, AND RETAIL VALUE OF THE BOVINE CARCASS

By

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TABLE OF CONTENTS

LIST OF TABLES

FIGURE

Figure   Page

CHAPTER I

INTRODUCTION

The meat industry accounts for 9% of the energy used by the entire food industry (Rosoff, 1975). After an extensive survey, the Federal Energy Administration, in 1976, established a 12% energy conservation target for the meat packing industry (Unger, 1977). This conservation target is to be achieved by 1980. Therefore, it is apparent that a more efficient method of processing the beef carcass is needed.

Many different methods of processing the bovine carcass have been utilized by the beef industry. Traditionally, beef sides are chilled at the slaughter plant for a minimum of 24 hours before being transported, as sides or quarters, to retail outlets where the carcasses are then processed into retail cuts. More recently, beef sides have been processed after a 24 hour chill into vacuum packaged wholesale cuts or "boxed beef" at the slaughter plants prior to shipment. Even though the boxed beef approach is more efficient in certain respects, waste fat and bone are chilled and transported.

Hot muscle boning, a relatively new processing method involving seaming of lean meat from bone and excess fat prior to chilling, is currently being investigated at Oklahoma State University. Distinct reductions in cooler shrink and in the space and energy required for cooling the hot muscle boned beef have been alluded to in the literature. However, absolute amounts of these reductions have received very little study. Meaningful data are needed to facilitate a complete evaluation of hot muscle boning as an energy conserving alternative beef processing method.

It is imperative when evaluating processing methods to consider the quality attributes of the resulting product. Tenderness of hot muscle boned beef has been studied. However, the results vary considerably with different experimental procedures. If, in fact, a decrease in tenderness does result from hot muscle boning, mechanical, electrical or chemical tenderization methods may well alleviate this adverse affect.

The objectives of this study were:

1. To determine the yield of boneless, edible beef obtained by hot muscle boning.
2. To establish the amount of space and energy saved by cooling only the hot muscle boned product as compared to the entire carcass.
3. To compare the retail value of a hot muscle boned side to the retail value of a bone-in, cold processed side.

CHAPTER II

REVIEW OF LITERATURE

This review of literature will be concerned with previous research generally pertaining to the bovine in the area of hot muscle boning or hot processing.

Hot Processing

One of the earliest articles concerned with the removal of muscle from the carcass soon after slaughter was by Ramsbottom and Strandine (1949) who found that beef in the form of boneless cuts chilled at a faster rate than as sides of beef. The boneless loin section of one side of each of two Choice grade carcasses was dissected about one hour following slaughter. The maximum difference in temperature between the boneless loin section and the loin in the companion side occurred two to eight hours post mortem when the boneless loins were 10° to 15°F lower. By 24 hours post-slaughter, both the boneless and control loins had dropped below 40°F. The effect of boning before chilling on tenderness was estimated using steaks cut from the longissimus dorsi (LD) at 3, 6, 9, and 12 days post mortem. Muscles which were dissected from the sides prior to chilling yielded steaks which were less tender than those which remained intact in the side until it was chilled. In another phase of the study, all loins were removed from the side at the time of slaughter. Steaks from the boneless loins were cut and cooked at 2, 5, 8, 11, 14 hours and 1, 2, 3, 6, 9, 12 days post mortem and evaluated for tenderness. Beef was more tender at 2 hours after slaughter than any other time prior to 2 days, after which time the meat became progressively more tender.

Mandigo and Henrickson (1966) evaluated the yield, tenderness, juiciness, flavor, and moisture content of hot processed hams cured and smoked prior to chilling. Comparisons with conventional processing indicated that the hot processed product was of equal or superior quality. Using fresh pork, Henrickson (1967) found cutting and fabrication of pork to a retail form prior to initial chilling provided cuts which have quality equal to the conventionally processed products. Henrickson (1968) evaluated the tenderness of hot processed pork using the Warner-Bratzler shear machine and found no significant difference by hot processing of porcine muscles. He also suggested that it is impractical to chill or heat bone and waste fat with the same expensive equipment and facilities used for the high-value edible portion of the carcass.

Schmidt and Gilbert (1970) used carcasses from Angus steers and bulls of differing maturities to compare pre-rigor excised muscles subsequently held at 15°C for 24 or

48 hours to control muscles excised post rigor from the opposite side which was chilled at 9°C for 24 hours. The excised muscles (anterior LD, posterior LD, semimembranosus, SM, and semitendinosus, ST,) were vacuum packaged and stored at 15°C until the end of their 24 or 48 hour conditioning period. Shear force values for the control and pre-rigor muscles held for 24 hours were similar for all muscles except for the ST. With the exception of the SM, the same muscles became significantly more tender than the controls after and additional 24 hours conditioning at 15°C. The control ST had a lower shear force value than either of the treatments. Microbiological examinations revealed all treatments had acceptably low bacterial numbers. This investigation showed that organoleptically acceptable meat of a satisfactory microbiological standard can be produced by pre-rigor excision of prime cuts from beef carcasses. They concluded such a procedure could produce considerable saving in by-passing the conventional beef chiller while ensuring a "standard product".

The hypothesis that hot boning the beef carcass is economically favorable was supported by Brasington and Hammons (1971) who indicated that on-the-rail boning resulted in higher meat yield than normal table cutting. In addition, the rail method allowed lower wage rates due to the use of semi-skilled workers during a portion of the operation. The operation was reported to be more flexible as to line arrangement, more sanitary, and less fatiguing to workers.

Marsh et al. (1972) excised pork muscles from the hot carcass and exposed them to 0°C. Complete excision of muscles was compared to routine processing of the entire carcass. Excision and cold exposure of seven muscles produced significant toughening in the LD, dark ST, triceps brachii and rectus femoris. Toughening, although statistically non-significant, occurred in the light ST and gluteus medius (GM); however, almost no change in tenderness was found in the BF and psoas major compared to the control.

Hot processing of lamb and mutton was investigated by McLeod et al. (1973). Ten lambs and twelve ewe carcasses were halved at 1-2 hours post mortem on a band saw. One side was further broken into wholesale cuts. The bone-in cuts were wrapped in Cry-O-Vac film which was then heat-shrunk on the meat. The opposite side was left unwrapped and was suspended by the leg, and both the cuts and the sides were held at 10°C for 24 hours. The meat was then frozen, and the side was sawed into similar wholesale cuts. When the lamb meat was examined for tenderness, no differences were found between the hot cut and control shoulders and loins. However, muscles of the leg, (SM, BF, and GM) were significantly more tender from the hot cut legs. In mutton, hot cutting decreased tenderness of the loin, but increased tenderness in the leg. No differences were observed in other palatability characteristics, such as flavor or juiciness, between the conditioned cuts and the conditioned sides.

Kastner et al. (1973) assigned six Hereford steer carcasses to each of three holding periods (either two, five or eight hours post mortem). One side was hot boned after its designated holding time at 16°C, while the opposite side of each carcass was cold boned after chilling for 48 hours at 2°C. Muscles excised at five and eight hours post mortem shrunk significantly less than the cold boned muscles, but the force required to shear steaks from the two and five hour periods was greater than for the controls. Meat from the five and eight hour holding periods was lighter colored, while the two hour treatment produced darker meat. No significant differences were found between treatments and control for % of moisture, % crude fat or % cooking loss. When the hot boned sides were held intact for eight hours, and then fabricated, the hot boned steaks were equal or superior to the cold boned steaks for all characteristics examined.

Schmidt and Keman (1974) hot boned and vacuum packaged the right sides of six Angus steer carcasses, while the left sides were cold boned as controls after eight days chill at 1°C. There was no significant difference in shear force, flavor, juiciness, tenderness, or overall acceptability between hot and cold boned muscles.

Follet et al. (1974) excised the SM muscles from the left sides of each of 24 North Devon steer carcasses at one hour post mortem. The muscles were vacuum packaged and chilled at either -5°, 5°, 10°, or 15°C for 24 hours and then stored at 0°C for the duration of the experiment. The SM muscles from the right sides of the same carcasses were removed after 36 hours at 2°C and stored with the prerigor excised muscles. All results were given in comparison to the 36 hour excised muscles. They observed a substantial reduction (30-90%) of loose drip in the vacuum packaged meat with cooling between 5°C and 15°C, minimal discoloration, improvement in tenderness with conditioning at 5°C to 15°C, and progressively increased bacterial counts as the cooling temperature was raised.

Falk et al. (1975) used 30 Choice Angus steer carcasses to evaluate the tenderness of hot boned beef. Hot boning at three, five or seven hours post mortem was compared to cold boning the opposite side of each carcass after a 48 hour chill at 1°C. Differences in shear force values between hot versus cold boned muscle were small, averaging less than 0.90 Kg. Although there was a definite trend showing that hot boned steaks were less tender, only the LD boned at five hours and the SM boned at seven hours were significantly ($P < .05$) less tender.

Kastner and Russell (1975) evaluated tenderness, flavor, and color of bovine muscle held at 16°C and excised at six, eight, or ten hours post mortem as compared to muscles held at 2°C and excised 48 hours after death. Panel evaluation for flavor and color revealed no significant differences between any of the treatments. Shear force values were significantly higher for the six hour treatment when compared to muscles held for 48 hours before excision. The eight and ten hour conditioning periods produced meat with tenderness equal to that of the control.

Tenderness of hot processed beef was examined by Dransfield et al. (1976). They found when individual muscles were excised soon after slaughter and held at 10°C for 24 hours prior to chilling, the eating quality was, in general, equal to that of meat cut 24 hours after slaughter. Only in one muscle (the psoas major) was the hot deboned meat found to be substantially tougher by a consumer panel. Detailed examination by a shear test showed that hot deboning increased the toughness values by 10%.

Will and Henrickson (1976) utilized 12 Choice steer carcasses to examine the effect of muscle removal at three delayed chilling periods (three versus 48 hours, five versus 48 hours, and seven versus 48 hours) and relate this to meat tenderness. One side of each carcass was held at 1.1°C for a 48 hour post mortem conditioning period before the BF, LD, and SM muscles were excised. The opposite sides receiving the delay chill treatment were held at 16°C for the three, five or seven hour post mortem conditioning period before the same muscles were removed. For the three versus 48 hour treatment, the Warner-Bratzler shear (WB) indicated the three hour BF was significantly more tender. Nip Tenderometer (NT) readings suggested the five hour LD was more tender than the 48 hour control. When comparing the seven and 48 hour treatments, both the WB and NT showed the seven hour SM to be significantly less tender. For all three conditioning time comparisons, no significant differences were observed by a trained taste panel. Objective and subjective data led to the conclusion that no major differences in meat tenderness existed between muscles which were boned at three, five, or seven hours post mortem and those that were allowed to remain on the suspended carcass for 48 hours.

Tenderness of hot boned bovine longissimus dorsi muscle was investigated by Kastner et al. (1976). Hot boned longissimus dorsi muscles were excised from the side at six, eight, or ten hours post mortem. Control muscles were removed from the opposite sides after 48 hours at 2°C. Hot boned steaks for all three holding periods were more tender than the 48 hour controls, but the differences were not statistically significant.

Pierce (1977) found that beef boned at two hours post mortem from electrically stimulated sides was significantly more tender than non-stimulated controls. This work suggested electrical stimulation may be an effective method to counteract a possible toughening effect of hot boning.

Yield

Henrickson and Smith (1967) found the yield of pork wholesale cuts removed within 30 minutes post mortem was not significantly different from the yield of cuts obtained after a 24 hour chill. Henrickson (1967) also reported no significant difference between hot and cold cutting yields of ham, but during curing and cooking, hot processed hams tended to lose less weight.

Kastner (1972) and Kastner et al. (1973) using the procedure previously described, evaluated the percent loss (yield) of hot boning a side compared to the cold boning procedure. The formula used for calculating percent loss for the 2 hour holding period was:

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

For the 5 and 8 hour holding periods, the following formulas were used:

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

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

For all holding periods, the hot boned treatment had a smaller average percent loss than the control. The difference between percent loss for hot and cold boning in the 2 hour holding period was statistically non-significant; however, in the 5 and 8 hour holding periods, significant differences existed between the two procedures.

Retail yield of beef was examined by Schmidt and Keman (1974) using their procedure already described. Weights of lean trim and boneless cuts were used to calculate retail yield as a percent of hot side weight for both the hot and cold boned sides. The percent retail yield was significantly higher for the hot boned side. More fat was left on the hot boned roasts, since it was difficult to remove a similar amount of fat from both sides. However, there was no significant difference in the percent fat trim or bone between treatments.

Similarly, Falk (1974) using a procedure previously described, produced a streamlined hindquarter by removing the chuck, brisket, shank, plate, and flank. The streamlined hindquarter was then processed into its components of fat, bone, and lean, and the percent loss (yield) of the hot boned side was calculated as follows:

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

A = Intact Streamlined Hindquarter Weight

B = Sum of Streamlined Hindquarter Components

At the expiration of 48 hours post mortem, the cold boned side was reweighed, and the percent loss calculated using the following formula:

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

Sides which were hot processed exhibited significantly less cooler shrinkage at the three ($P = .06$), five, and seven ($P < .001$) hour holding periods as compared to the corresponding 48 hour control sides.

Kastner and Russell (1975) used 15 Good and Choice grade heifers to evaluate yield (percent loss) using their procedure previously described. At the appropriate time (6, 8, or 10 hours post mortem) the side assigned the hot boning treatment was fabricated into lean trim, fat trim, bone, and intact muscles and muscles systems. Each component was placed in Cry-O-Vac bags and placed in the 2^{o}C cooler with the control side. At 48 hours post mortem, the control half was fabricated in the same manner as the hot boned side. Upon complete fabrication, the components of each side were weighed and totaled. The yield, expressed as percent loss, was calculated based on the initial weights of the carcass halves. Hot boned sides were consistently lower in percent loss; however, only for the 10 hour holding period was the difference statistically significant.

Cooling Space

McLeod et al. (1973) reported that if conditioning of hot processed lamb could be satisfactorily accomplished as wrapped cuts in cartons, space requirements for conditioning would be reduced to about a tenth of those for the present processing method.

Henrickson et al. (1974) projected a 30% to 35% reduction in the amount of chilling space if beef was hot muscle boned and chilled rather than handled in the conventional manner.

American Society of Heating, Refrigeration, and Air Conditioning Engineers (1974) reported common cooler space values per beef carcass of 90 x 36 x 30 inches or 97,200 cubic inches. In practice, however, sides may be crowded more closely together, so less space would be required. If the space above and below the carcass (which is necessary for adequate air distribution) is included, a total of 220,320 cubic inches would be required per carcass.

The refrigerated space commonly set aside for the chilling of a 600 pound beef carcass is 80 x 36 x 30 inches or 86,400 cubic inches (Henrickson and McQuiston, 1977). Space above and below the hanging carcass usually takes an additional 34,000 cubic inches making a total of 120,400 cubic inches. The boxed space required for each 600 pound carcass is estimated to be 90,000 cubic inches. By contrast, the edible portion of a hot muscle boned 600 pound carcass can be cooled in about 26,000 cubic inches (21.6%) of space either on a conveyor belt or on shelves.

Henrickson and Furguson (1977) reported up to a 65% savings in transportation space. Truckers could haul much larger quantities and reduce the number of repeated trips.

Cooling Energy

Because the hot muscle boning process would require chilling of only edible meat and not excess fat and bone, a distinct savings in cooling energy should accrue. Furguson and Henrickson (1975) predict over 9,000 less BTU's would be required to cool the edible portion from a 600 pound carcass than is now necessary by the regular commercial practice.

A Choice carcass weighing 600 pounds will require 31,500 BTU's of energy transfer to reduce it from 102^{o}F to 32^{o}F. The edible portion of the same carcass (420 pounds) would require removal of only 22,050 BTU's to lower the same edible product to 32^{o}F, (Henrickson and McQuiston, 1977).

Advantages of Hot Processing

Several potential advantages for hot processing the bovine carcass have been reported in the literature. Many of the advantages are dependent on the removal of excess fat and bone prior to chilling or further processing (Henrickson and Smith, 1967; Kastner et al., 1973; Will, 1974, Henrickson et al., 1974; Falk et al., 1975; Dransfield et al., 1976; Henrickson and McQuiston, 1977; and Henrickson and Furguson, 1977). By removing the excess fat and bone, substantial reductions in the space required and the amount of heat transfer necessary for cooling the meat would be possible (Kastner et al., 1973; Will, 1974; Henrickson et al., 1974; Falk et al., 1975; Furguson and Henrickson et al., 1975; Cia and Marsh, 1976; Dransfield et al., 1976; Davey et al., 1976; Mandigo et al., 1977; and McCollum, 1977). As a result of subdividing the carcass prior to chilling, a decrease in chilling time and a more rapid product turnover rate may be realized (Kastner et al., 1973; Will, 1974; Henrickson et al., 1974; Cia and Marsh, 1976; Mandigo et al., 1977). Transportation costs for distribution of meat could be reduced simply because only edible product would be handled (Kastner et al., 1973; Will, 1974; Furguson and Henrickson, 1975; Henrickson and Furguson, 1977). Properly handled hot boned meat would have a lower potential for microbial contamination because of rapid chilling and faster movement through the processing plant (Will, 1974; Davey et al., 1976). Removal of muscle from the carcass and placement of the meat into Cry-O-Vac bags would enhance the yield of boneless meat as weight loss due to evaporation could be kept at a minimum (Will, 1974; Cia and Marsh, 1976; Dransfield et al., 1976). Many of the advantages of hot processing beef may also be realized by the pork and lamb industries (Henrickson and Smith, 1967; McLeod et al., 1973; Devine et al., 1975; and Mandigo et al., 1977).

CHAPTER III

MATERIALS AND METHODS

A total of 25 slaughter weight steers and heifers of mixed breeding were utilized in this investigation. The cattle were stunned by a captive bolt percussion stunner, bled, skinned, eviscerated and split in the conventional manner. After splitting, hot weight was recorded individually for the right and left sides, which were both suspended vertically by the Achilles tendon. One side of each carcass was randomly chosen to be hot muscle boned and was moved into a 16°C room.

At four hours post mortem, the side to be hot muscle boned was taken to a 24°C room where the on-the-rail boning procedure was performed. A circular scribe saw was used to cut through the dorsal processes of the lumbar and thoracic vertebrae close to the body of the vertebra to facilitate complete removal of the longissimus dorsi (LD) more conveniently. The front appendage was removed, cutting as close as possible to the medial face of the scapula. From this appendage, the supraspinatous (SS) and a boneless outside chuck roast consisting of the muscles on the lateral side of the scapula were obtained. A boneless inside chuck roast was then taken from the side by removing the muscles lateral to the first six ribs, being careful not to cut into the LD until the third rib area and to leave the deep and superficial pectoral muscles intact for later removal as a boneless brisket roast. The normal point of separation between the chuck and rib is between the fifth and sixth ribs; however, the author felt more efficient use of the meat in the side could be achieved if the inside chuck roast extended posteriorly until the anterior edge of the seventh rib. Both the inside and outside chuck roasts were rolled and Jet-Netted in #60 net. Muscles of the flank, plate, and brisket were then removed to reduce the weight on the Achilles tendon and muscles of the round. A flank steak (rectus abdominus) and a boneless brisket roast (deep and superficial pectorals) were recovered, and the rest of the muscle in the flank-plate-brisket mass of meat was utilized as lean trim. Next, the muscles of the round were removed while trying not to cut the epimysium so moisture loss could be kept at a minimum. The gracilis, semimembranosus (SM), adductor, and pectineus were removed together, and for convenience will hereafter be referred to as merely the SM. Next, the semitendinosus (ST), biceps femoris (BF) and gluteus complex (GM) consisting of the gluteus medius, gluteus accessorius, and gluteus profundus were excised. The psoas major (PM), psoas minor, and illiacus were removed together to assure complete excision of the illiacus with the PM. The quadriceps (vastus intermedius, vastus lateralis, vastus medialis, and rectus femoris) and the LD (including the multifidous dorsi, longissimus costarum, and spinalis dorsi) posterior to the third rib were finally excised from the side. The muscle still remaining on the skeleton was removed and used as lean trim for ground beef. An effort was made to separate enough fat for the lean trim to be 20% fat. The muscles, muscle systems, and lean trim were wrapped individually in Avisco Cellophane (no vacuum drawn) and chilled in a 1.1^{O}C cooler. Separated fat and bone were weighed and recorded. Side dissection was completed in approximately one and one-half hours.

After 48 hours at 1.1^{O}C, the hot muscle boned meat was removed from the Avisco Cellophane, trimmed to a maximum of 0.25 inch (0.635 cm) of external fat, and individually weighed. Accurate trimming could not be performed on the hot fat, so the 48 hour chill was necessary to obtain a standard trim on all muscles. Fat trimmed from the muscles was "added in" to the original fat weight obtained the day the side was dissected.

The muscles and muscle systems were removed in the manner described in an attempt to maximize the potential use of the meat as steaks, roasts, or ground beef. The seventh rib chuck separation is one example of this attempt. Another example is the utilization of the LD for steaks from its origin at the ilium to the third rib, while under normal cutting procedures, the LD anterior to the sixth rib would be included in chuck roasts.

Yield

Twenty-five sides were used to obtain total edible lean per hot muscle boned side. This was accomplished by totaling the weights of all the cuts and lean trim after the 48 hour chill and fat trim procedure. By trimming the chilled cuts to a constant 0.25 inch (0.635 cm) external fat cover, it was hoped to add consistency and reliability to the estimate of total edible lean per side. The percent yield of edible lean for each side was calculated as follows:

$$\frac{\text{Total Edible Lean}}{\text{Hot Side Weight}} \text{ X } 100 = \text{Percent Yield}$$

It should be noted that these cuts and percent yield represent boneless, closely trimmed, completely edible lean.

Cooling Space

Sixteen sides were used to evaluate the amount of cooler space required by the vertically suspended (Achilles tendon) intact side, and the amount of space necessary to cool only the edible product obtained by hot muscle boning that side. Immediately before hot boning a side, the intact side was measured for length, width, and depth at the side's longest, widest, and deepest points (See Figure 1). These three measurements were multiplied together to obtain the required cooler space (in cubic centimeters) for the intact side. The side was hot muscle boned as previously described after the measurements were taken. After the pieces had been chilled (48 hours) and trimmed, each individual cut was measured in the same manner as was the side, and the space, in cubic centimeters, required for each cut was calculated. Total space for the hot muscle boned product was derived by adding together the space requirements for all the pieces of the side. The formula used for calculating percent space was the following:

$$\frac{\text{Total Space for Hot Muscle Boned Product}}{\text{Intact Side Space Requirement}} \times 100 = \text{Percent Space}$$

Cooling Energy

The amount of heat energy transfer (cooling energy) required to chill the meat was investigated using 25 sides. The energy transfer (in kilocalories) necessary for a 1°C drop in meat temperature was obtained by multiplying the weight of the meat by the specific heat of the meat. A value of 0.75 kilocalorie per kilogram per degree Celsius was used as the specific heat for the intact side (American Society of Heating, Refrigeration, and Air Conditioning Engineers, 1974), and 0.82, 0.69, 0.50 kilocalorie per kilogram per degree Celsius were used as the specific

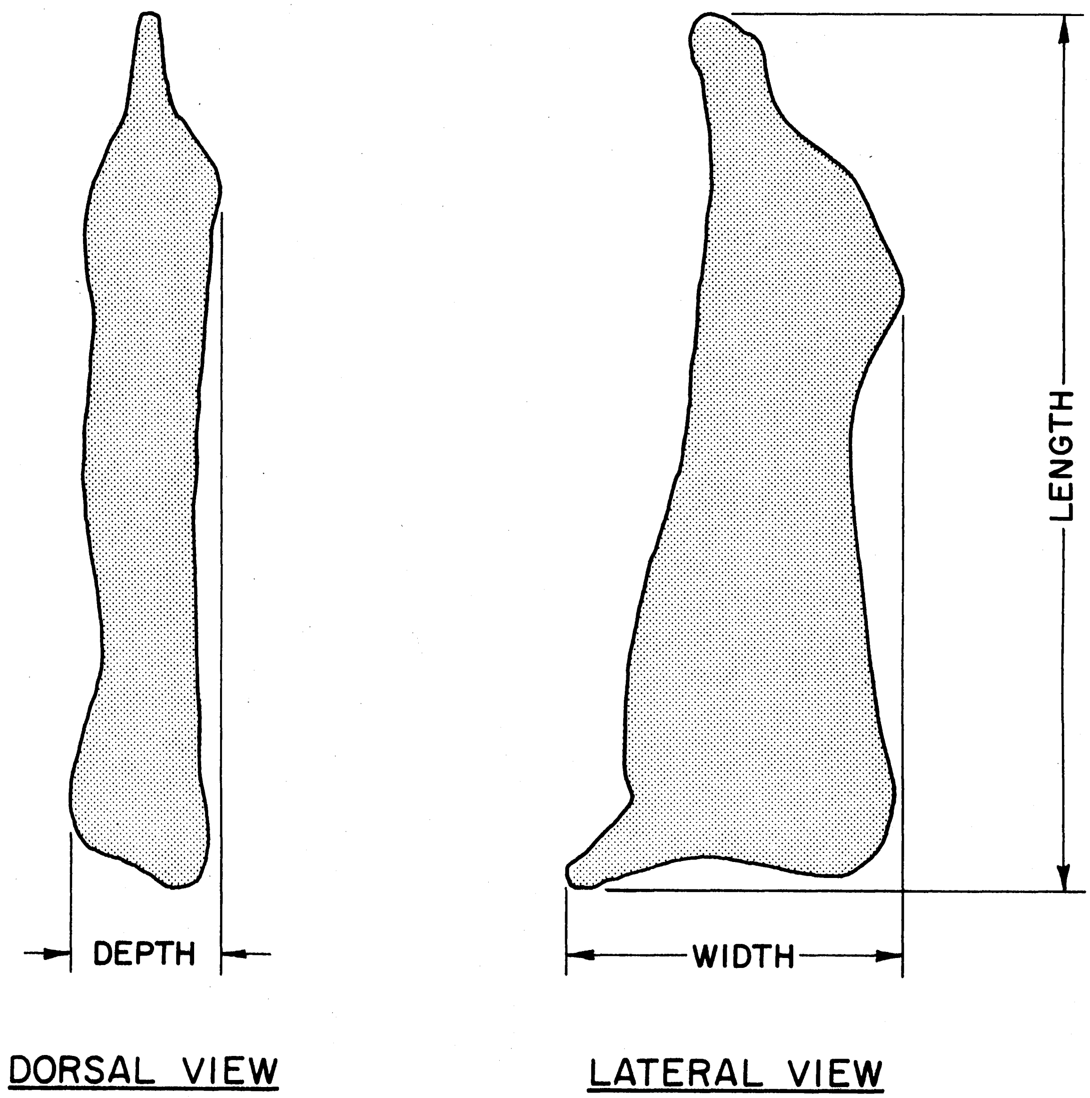

Figure 1. Beef Side Showing Length, Width, and Depth Dimensions

heats for lean beef, fat, and bone respectively (Ordinanz, 1946; Morely, 1972). Energy required for a 1°C drop in meat temperature was calculated as follows:

$$\text{Side Weight} \times 0.75 \times 1^{\circ} = \text{Energy for Intact Side}$$

$$\text{Total Edible Lean Weight} \times 0.82 \times 1^{\circ} = \text{Energy for Hot Muscle Boned Product}$$

$$\frac{\text{Energy for Hot Muscle Boned Product}}{\text{Energy for Intact Side}} \times 100 = \text{Percent Energy}$$

Fat and bone energy requirements were calculated in a similar manner by substituting the weight and specific heat for the respective components of the beef side. In this investigation, a 1°C drop in temperature was calculated, but the relationship between the intact side and the hot muscle boned product would be identical regardless of how many degrees the meat temperature was changed above the freezing range.

Retail Value

Eight carcasses were used to compare the retail value of the hot muscle boned side to the value of the opposite conventionally cold processed side. After slaughter, one side of each carcass was placed in a 1.1°C chill cooler while the other side was hot muscle boned as previously described. Forty-eight hours after hot boning, the muscles and muscle systems were further processed into retail cuts. Following a seven day chill at 1.1°C, the opposite side was processed into bone-in retail cuts according to conventional cutting procedures. Cuts obtained from the cold processed side were blade chuck roasts, arm chuck roasts, cross cut shank soup bones, brisket roast, short ribs, rib steaks, rib roast, flank steak, club steaks, T-bone steaks, porterhouse steaks, sirloin steaks, eye of the round roast, inside round roast, outside round roast, boneless rump roast, sirloin tip roast, and ground beef (20% fat). The cuts were trimmed to a maximum fat cover of 0.25 inch (0.635 cm), and "tails" were cut from the rib, club, T-bone, and porterhouse steaks at 1.5 inches (3.8 cm) lateral to the longissimus dorsi. Retail prices per pound for each of the cuts were obtained from three retail outlets in Stillwater, Oklahoma, on November 23, 1976. Retail price per pound was multiplied by the weight of the corresponding cut to get cut value. Cut values were totaled to obtain side value for each side and cutting procedure.

Statistical Analysis

All data presented in this study was analyzed by the use of the SAS computer programming system (Service, 1972.) The research was designed to be analyzed as a Completely Randomized Block Design, with each carcass comprising one block. The Analysis of Variance in conjunction with the F-test was used to analyze differences in the space, energy, and retail value comparisons. The Analyses of Variance appear in the Appendix.

CHAPTER IV

RESULTS AND DISCUSSION

Mean values of various carcass traits for the sides utilized are presented in Table I. The mean side weight was 124.96 kilograms while the average Yield Grade was 3.23. These values are reported only as a description of the population of cattle used, since no attempt was made to relate these traits to the results of this study.

Yield

Mean values for the weight of the cuts and percent yield of the lean, fat and bone components of the hot muscle boned sides appear in Table II. An average of 62.4% of the side weight was recovered in boneless, edible lean beef. This yield value compared very closely to the yield reported by Schmidt and Keman (1974) who found a significantly greater yield from hot boning when compared to the opposite side of the carcass which was cold boned after an eight day chill. In this research, the opposite side was not available for cold boning, so no direct comparison between the two methods could be made. However, it has been previously stated (Chapter II)

TABLE I

BEEF CARCASS TRAIT MEANS

Trait	Mean Value	Standard Error of Mean
Side Weight (Kg)	124.96	4.64
Rib Eye Area (sq cm)	69.48	1.87
Kidney, Pelvic and Heart Fat (%)	3.58	0.18
Fat Thickness at 12th Rib (cm)	1.19	0.13
Yield Grade[a]	3.23	0.18

[a]Yield grade designated as U.S. No. 1, 2, 3, 4 or 5

TABLE II

WEIGHTS AND YIELDS OF HOT MUSCLE BONED BEEF SIDE COMPONENTS

Component	Mean Value	Standard Error of Mean
Side (Kg)	124.96	4.64
Outside Chuck (Kg)	5.76	0.25
Inside Chuck (Kg)	6.91	0.40
Supraspinatus (Kg)	0.91	0.06
Psoas major (Kg)	2.09	0.09
Longissimus dorsi (Kg)	7.87	0.43
Gluteus complex (Kg)	2.73	0.10
Biceps femoris (Kg)	5.01	0.21
Semimembranosus (Kg)	6.41	0.20
Semitendinosus (Kg)	1.71	0.06
Quadriceps group (Kg)	4.11	0.14
Lean Trim (Kg)	31.11	1.24
Brisket (Kg)	3.84	0.27
Flank Steak (Kg)	0.69	0.05
Total Lean (Kg)	77.94	2.96
Fat Trim (Kg)	24.92	1.44
Bone (Kg)	19.60	0.77
Lean Yield (%)	62.40	0.64
Fat Yield (%)	19.70	0.72
Bone Yield (%)	15.82	0.45

that several investigators (including Schmidt and Keman, 1974) have either reported or speculated that less loss due to cooler shrink would occur with the hot muscle boning procedure.

Visser and Airah (1976) stated that weight loss from warm, freshly killed meat is due to three major factors: a. the difference in water vapor pressures between that on the carcass surface and of the surrounding air; b. evaporative losses brought about by forced air circulation over the carcass; c. evaporative losses due to heat flowing through the carcass surface evaporating moisture. By hot muscle boning and vacuum packaging the cuts, all three of these factors would be eliminated, since no evaporation would occur from the moisture barrier of the vacuum packaging material.

Lovett et al. (1976) reported that in a well designed and well run chiller approximately 2% of the initial carcass weight is lost due to evaporation of water from the surface of the carcass. In other chillers, losses up to 4% have been reported. About 62% of the initial 24 hour cooler shrink of a beef carcass occurs within the first eight hours of that period (American Society of Heating, Refrigeration, and Air Conditioning Engineers, 1974). This further emphasizes that quick placement of hot cuts into vacuum packaging will reduce weight loss during cooling.

In this investigation, the hot cuts were not vacuum packaged, but merely wrapped in a moisture vapor barrier transparent material which was not air tight, so some evaporation presumably occurred. The hot cuts were not vacuum packaged because they had to be unwrapped and trimmed after a 48 hour chill. It should be noted that very little meat juice was observed in the wrap at the time of trimming, and the cuts with epimysium still intact and completely surrounding the muscle showed almost no fluid loss.

Theoretically, lean yield, fat yield, and bone yield should total 100%. However, these three components account for only 97.92% of side weight for the hot muscle boned side. There are several possible reasons for this 2.08% discrepancy. The sides were weighed on a rail scale immediately after slaughter and washing, so perhaps excess water was still on the side when it was weighed. During the four hour period between exsanguination and hot muscle boning, some of this excess water would have evaporated, and also some blood still in the carcass could have been lost in the form of drippings. Some evaporation from the muscles undoubtedly occurred after they were excised from the side and before they were wrapped in Avisco cellophane. Some cutting loss was also probably realized during the boning. These reasons, plus possible inaccuracies in weighing the side on the rail scale and weighing the pieces after excision, could account for the 2.08% loss in side weight. Schmidt and Keman (1974) also reported a loss of

2.7% in side weight, since the lean, fat, and bone totaled to only 97.3% of side weight.

Cooler Space Requirements

The amount of cooler space required by the intact, vertically suspended side, and the space needed by each piece of lean beef is recorded in Table III. The total space for the hot muscle boned meat was obtained by adding together the individual space requirements for each of the cuts removed from the side. The mean of 122,818.26 cubic centimeters for the total space for the hot muscle boned product is not a true estimate of the total cooler space needed by the hot muscle boned meat. This estimate would be accurate only if it was assumed that when combining the cuts from the side, a perfect rectangle would be formed. This, however, is not a valid assumption because when the cuts are combined, a rectangle will not result and some extra, wasted space would be required for this group of cuts. Wasted space around the intact carcass is the major reason that hanging carcasses from the rail causes a very inefficient utilization of cooler space. The author does not know to what extent wasted space will occur in combining the hot muscle boned cuts, but would expect it to be a very small amount in relationship to the space wasted by the intact side. For this investigation, it was necessary to assume that the cuts would combine with no wasted space, and this fact should be remem-

TABLE III

COOLER SPACE REQUIREMENT OF HOT MUSCLE BONED COMPONENTS

Components	Mean Space Requirement (cu cm)	Standard Error of Mean
Beef Side	648,199.33	39,747.48
Outside Chuck	9,384.54	543.23
Inside Chuck	10,453.14	950.78
Supraspinatus	1,587.25	148.14
Psoas major	3,500.77	235.48
Longissimus dorsi	11,538.79	1,046.15
Gluteus complex	4,899.24	587.97
Biceps femoris	10,242.57	651.22
Semimembranosus	9,857.97	508.82
Semitendinosus	2,576.21	144.04
Quadriceps group	6,537.46	341.18
Lean trim	47,562.14	2,132.12
Brisket	6,804.24	839.67
Total Hot Boned Meat	122,818.26	6,541.72

bered when interpreting the results. If hot muscle boning were implemented in a large scale operation, all the cuts from a side would probably not be cooled and stored as a side, but rather in groups consisting only of one cut from many different carcasses. If, for example, only longissimus dorsi muscles were stacked together there would be little, if any, wasted space because of the similarity in shape of all the longissimus dorsi muscles.

Space requirements for the intact side and the hot muscle boned product are compared in Table IV. Less ($P < .01$) space was required by the hot muscle boned product (see Appendix Table XI), and if expressed as a percent of the intact side, only 19.12% as much cooler space was needed. This is explained by the fact that a substantial amount was wasted by the intact side due to curves and protrusions from the side such as the foreshank. The hot muscle boned pieces are not as irregularly shaped, and space needed to chill bone and excess fat is eliminated. Space above and below the side was not included in the space requirements for the intact side because this could vary considerably among different processing plants.

Cooling Energy

Mean values for the amount of heat energy transfer in kilocalories needed for a $1^{\circ}C$ change in temperature of the side and its components are shown in Table V. The relationship of side component energy transfer to intact

TABLE IV

SPACE REQUIREMENTS FOR THE INTACT SIDE AND HOT MUSCLE BONED PRODUCT

	N	Mean Cooler Space Requirement (cu cm)	± Standard Error
Intact Side	16	648,199.33	± 39,747.48
Hot Muscle Boned Product	16	122,818.26[a]	± 6,541.72
Percent Space		19.12%	± 0.43

[a]Significant difference ($P < .01$)

side energy transfer expressed as a percentage of intact side is also recorded in Table V. In theory, the heat energy transfer of lean, plus fat, plus bone, should equal the heat energy transfer for the intact side. This, however, does not occur with this data, and a mean difference of 2.83 Kcal is present. This discrepancy can be explained by two major reasons. First, the loss in weight noted in the investigation of yield would also effect the energy results. Heat energy transfer necessary for the intact side was calculated using hot carcass weight, and heat energy transfer needed for the components of fat, lean, and bone was calculated using the components' weight after hot muscle boning, which resulted in a 2.08% loss of side weight. This 2.08% cutting loss would account for 1.95 Kcal of the 2.83 Kcal discrepancy. Secondly, the specific heats for the intact side, fat, lean, and bone may not have been exactly the correct values for the beef utilized in this study. The specific heat of 0.75 Kcal/Kg/^{O}C for the intact side is merely a standard value for beef carcasses reported in the literature. This value would in reality change with the composition of the beef carcass because fat, lean, and bone have different specific heats. Also, perhaps the amount of soft tissue left on the bones in this study was different from that amount for which the specific heat of bone was intended.

A comparison of heat energy transfer requirements for the intact side and the hot muscle boned lean is shown in

TABLE V

HEAT ENERGY TRANSFER REQUIREMENTS FOR 1^{o}C CHANGE IN TEMPERATURE OF SIDE COMPONENTS

Components	Mean Heat Energy Transfer	Standard Error
Side (Kcal)	93.72	3.48
Lean (Kcal)	63.90	2.43
Fat (Kcal)	17.19	1.00
Bone (Kcal)	9.8	0.39
Lean/Side (%)	68.23	0.70
Fat/Side (%)	18.13	0.67
Bone/Side (%)	10.55	0.30

Table VI. Less ($P < .01$) heat energy transfer was necessary for the hot muscle boned product, and only 68.23% as much as required by the intact side (Appendix Table XII). The difference in heat energy transfer was simply due to the fact that bone and excess fat was not chilled.

It should be remembered that these values are mathematical calculations that theoretically represent the greatest possible difference between the hot muscle boned product and the intact side. Only the amount of heat energy transfer needed by the product was considered, so the amount of actual energy savings will depend on the efficiency of the cooling unit and room where the meat is to be chilled.

In this investigation, a $1^{\circ}C$ drop in temperature was calculated, but the relationship between the hot muscle boned product and the intact side would be identical regardless of how large a temperature change (above freezing) was achieved. Therefore, the greatest absolute saving in cooling energy would be realized if the side was hot muscle boned prior to any chilling after slaughter. This would result in maximum cooling of only the edible portion of the carcass.

Retail Value

Mean weights and values of cuts obtained by hot muscle boning and cold, bone-in processing appear in Table VII and Table VIII, respectively. Mean total side

TABLE VI

HEAT ENERGY TRANSFER REQUIREMENTS FOR THE INTACT SIDE AND HOT MUSCLE BONED PRODUCT

	N	Mean Heat Energy Transfer (Kcal)	± Standard Error
Intact Side	25	93.72	± 3.48
Hot Muscle Boned Product	25	63.90[a]	± 2.43
Percent Heat Energy Transfer		68.23%	± 0.70

[a]Significant difference ($P < .01$)

values for the hot and cold cutting procedures are compared in Table IX. The hot boned side had a significantly greater ($P < .01$) retail value than the conventionally cold, bone-in processed side, with a difference of $17.13 per side (Appendix Table XIII). This could allow $34.26 greater retail value by hot muscle boning the entire beef carcass.

One major assumption must be made before side retail values from the two cutting procedures can be validly compared. The assumption is that the meat from the two methods of processing was of similar quality. If the hot muscle boned meat was noticeably less tender because of the boning method, then it could not be priced on the same level as the more tender cold processed beef. However, as was discussed in Chapter II, some researchers found hot muscle boned beef to be of acceptable tenderness and quality. Therefore, the assumption was made, and the comparison was considered valid.

There are three major reasons for the increased value of the hot muscle boned side when compared to the conventionally processed side. First, there was simply more pounds of beef because of less weight loss due to cooler shrink. Reasons for less cooler shrink were previously discussed. Second, more of the meat from the hot muscle boned side was more efficiently utilized as higher priced steaks and roasts. This concept was explored in Chapter III. Third, the price per pound was greater for the bone-

TABLE VII

MEAN WEIGHTS AND RETAIL VALUES OF HOT MUSCLE BONED COMPONENTS

Components	Weight (lbs) ± S.E.	Price/lb ($)	Cut Value ($) ± S.E.
Outside chuck	12.54 ± 0.50	1.18	14.79 ± 0.59
Inside chuck	17.48 ± 1.04	1.18	20.62 ± 1.23
SS	1.96 ± 0.11	2.04	4.00 ± 0.22
PM	4.78 ± 0.11	3.00	14.32 ± 0.33
LD	18.49 ± 0.67	3.28	60.64 ± 2.21
GM	6.26 ± 0.17	2.00	12.52 ± 0.34
BF	11.02 ± 0.26	1.59	17.53 ± 0.41
SM	14.40 ± 0.32	1.79	25.78 ± 0.57
ST	3.91 ± 0.11	2.04	7.98 ± 0.23
Quadriceps	8.98 ± 0.22	1.69	15.17 ± 0.38
Lean trim	63.64 ± 1.45	1.00	63.64 ± 1.45
Brisket	8.28 ± 0.37	1.49	12.35 ± 0.55
Flank Steak	1.15 ± 0.26	2.29	2.63 ± 0.60
	Hot Muscle Boned Side Value		271.98 ± 5.61

TABLE VIII

MEAN WEIGHTS AND RETAIL VALUES OF COLD PROCESSED, BONE-IN CUTS

Cut	Weight (lbs) ± S.E.	Price/lb ($)	Cut Value ($) ± S.E.
Arm Roast	10.72 ± 0.31	1.15	12.33 ± 0.35
Blade Chuck Roast	22.75 ± 0.53	0.85	19.34 ± 0.45
Ground Beef	51.84 ± 1.59	1.00	51.84 ± 1.59
Brisket	5.06 ± 0.42	1.49	7.54 ± 0.63
Soup Bone	5.87 ± 0.55	0.59	3.46 ± 0.33
Short Rib	8.55 ± 0.84	0.78	6.67 ± 0.65
Rib Steak	8.74 ± 0.62	1.98	17.30 ± 1.22
Rib Roast	4.61 ± 0.12	1.98	9.13 ± 0.27
Flank Steak	1.29 ± 0.05	2.29	2.95 ± 0.11
Club Steak	2.61 ± 0.18	1.79	4.68 ± 0.32
T-Bone Steak	6.20 ± 0.72	2.28	14.14 ± 1.64
Porterhouse Steak	5.35 ± 0.48	2.35	12.57 ± 1.13
Sirloin Steak	16.69 ± 1.03	1.69	28.20 ± 1.74
Eye of Round Roast	3.60 ± 0.16	2.04	7.34 ± 0.32
Outside Round Roast	7.44 ± 0.67	1.59	11.82 ± 1.06
Inside Round Round Roast	14.25 ± 0.76	1.79	25.51 ± 1.36
Sirloin Tip Roast	7.21 ± 0.55	1.69	12.19 ± 0.93
Rump Roast	4.89 ± 1.09	1.69	8.26 ± 1.84
	Cold Processed Side Value		254.85 ± 5.00

TABLE IX

MEAN SIDE RETAIL VALUE FOR HOT AND COLD PROCESSING METHODS

Method	N	Side Value ($)	± S.E.
Hot	8	271.98[a]	± 5.61
Cold	8	254.85	± 5.00
Difference between methods 17.13			

[a]Significant difference ($P < .01$)

less items. Boneless cuts should have a higher value per pound because there is no inedible bone in the product. However, additional labor is required to remove the bone from the cut, so undoubtedly the retail price per pound included the increased cost of extra labor. It was not the purpose of this investigation to examine the labor costs for the hot muscle boning procedure. Therefore, the author made no attempt to correct the prices of the boneless retail cuts for labor. It is suggested that time and labor studies on hot muscle boning be initiated.

It should be remembered that retail prices from one day were used to calculate all retail value data. Admittedly, prices change from day to day and week to week, but the general relationship of high priced cuts to lower priced cuts should remain fairly consistent. As a result, even though total side values would change with fluctuations in retail price, the difference in value between the two cutting methods should remain relatively constant.

It should also be noted that only one cutting procedure was utilized with the cold processed side. Different procedures could alter the relative yields of particular cuts within the cold processed side and resultantly change the side retail value. A major objective of this phase of the investigation was to compare hot muscle boned meat to the form of meat generally presented to consumers. Therefore, the "conventional" cold cutting procedure used in this investigation was chosen because it produced retail cuts commonly found in retail meat outlets.

A summary of the parameters examined comparing hot boned sides and intact sides is shown in Table X.

TABLE X

PARAMETER MEANS OF HOT BONED AND INTACT BEEF SIDES

Parameter	Hot Boned Side	Intact Side	Hot Boned side as % of Intact Side
Cooler Space (cu cm)	122,818.26	648,199.33	19.12
Cooling Energy (Kcal)	63.90	93.72	68.23
Side Retail Value ($)	271.98	254.85	106.72

CHAPTER V

SUMMARY AND CONCLUSIONS

Hot muscle boning of Good and Choice grade carcasses was examined to determine the effect of this processing method on lean beef yield, cooler space requirements, cooling energy transfer requirements, and retail dollar value. One side of each of twenty-five beef carcasses was hot muscle boned four hours post mortem. Thirteen major muscles and muscle systems were seamed from the side while the fat and muscle were still warm and pliable. Muscles were trimmed to a constant 0.635 cm external fat thickness, and lean trim was defatted so that it was approximately 20% fat. Total lean yield per side was obtained by adding together the weights of the thirteen muscles and muscle systems. An average yield of 62.4% of hot carcass weight was obtained in the form of totally boneless, completely edible beef. Cooler space requirements for the intact side was determined by measuring the side for length, width, and depth and multiplying these measurements. The muscles and muscle systems obtained by hot muscle boning the side were individually measured and space requirements calculated. The space needed by each of the muscles was added together to arrive at the amount of cooler space required by only the hot muscle boned product. Similarly, heat energy transfer required for a $1^{\circ}C$ drop in meat temperature was calculated for both the intact side and the lean beef obtained by the hot muscle boning procedure. Eight carcasses were used to compare retail dollar value of a hot muscle boned side to the value of a conventionally, cold, bone-in processed side.

The hot muscle boning procedure exhibited distinct advantages when compared to the conventional method of beef processing. Significant ($P < .01$) reductions in the space (525,381.07 cu cm) and heat energy transfer (29.82 Kcal) required to cool the meat from a side were observed with the hot muscle boning procedure. The retail value of a hot muscle boned side was significantly ($P < .01$) greater ($17.13) than the value of a conventionally processed side. This increase in retail value was not corrected to reflect the cost of additional labor required for boneless retail cuts.

These results indicate that hot muscle boning could be feasible and advantageous from the standpoint of the parameters investigated as outlined in this study. Perhaps the greatest benefit of this alternative beef processing method is the potential for saving energy. This single result of hot muscle boning may hasten or, indeed, require the adoption of this procedure in light of the energy problem of this country.

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TABLE XI

ANALYSIS OF VARIANCE FOR COOLER SPACE REQUIREMENTS

Source	DF	Sum of Squares	Mean Square	F
Total	31	9,673,340,220.0		
Block[a]	15	938,037.862.2	62,534,857.48	1.83
Treatment	1	8,223,117,490.0	8,223,117,490.0	240.82[b]
Error	15	512,184,867.8	34,145,657.85	

[a]One carcass was a block
[b]Significant ($P < .01$)

TABLE XII

ANALYSIS OF VARIANCE FOR HEAT ENERGY TRANSFER REQUIREMENTS

Source	DF	Sum of Squares	Mean Square	F
Total	49	106,090.61		
Block[a]	24	49,844.11	2,076.84	20.25[b]
Treatment	1	53,785.57	53,785.57	524.54[b]
Error	24	2,460.93	102.54	

[a]One carcass was a block
[b]Significant ($P < .01$)

TABLE XIII

ANALYSIS OF VARIANCE FOR SIDE RETAIL VALUE OF HOT AND COLD PROCESSING METHODS

Source	DF	Sum of Squares	Mean Square	F
Total	15	4,348.752		
Block[a]	7	3,022.315	431.759	17.575[b]
Treatment	1	1,154.470	1,154.470	46.99[b]
Error	7	171.966	24.566	

[a]One carcass was a block
[b]Significant ($P < .01$)

TABLE XIV

MEAN DIMENSIONS OF HOT MUSCLE BONED SIDE COMPONENTS

Component	Length (cm) ± S.E.	Width (cm) ± S.E.	Depth (cm) ± S.E.
Side	218.22 ± 4.60	85.26 ± 1.90	34.35 ± 0.76
Outside Chuck	41.35 ± 1.99	19.78 ± 0.45	11.43 ± 0.18
Inside Chuck	42.23 ± 2.22	19.54 ± 0.45	12.26 ± 0.40
SS	26.34 ± 0.84	10.76 ± 0.48	5.44 ± 0.22
PM	46.59 ± 1.81	13.21 ± 0.36	5.62 ± 0.16
LD	77.90 ± 1.66	19.84 ± 0.63	7.25 ± 0.43
GM	26.22 ± 1.02	22.91 ± 0.72	7.83 ± 0.32
BF	49.58 ± 1.16	23.32 ± 0.52	8.76 ± 0.30
SM	32.92 ± 0.60	28.40 ± 0.55	10.43 ± 0.25
ST	30.02 ± 0.64	11.37 ± 0.29	7.49 ± 0.24
Quadriceps	25.99 ± 0.48	21.65 ± 0.53	11.52 ± 0.28
Lean Trim	70.17 ± 3.91	37.08 ± 0.83	18.68 ± 0.69
Brisket	38.95 ± 2.26	25.05 ± 0.66	6.67 ± 0.54

VITA

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Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF HOT MUSCLE BONING ON LEAN YIELD, COOLER SPACE REQUIREMENTS, COOLING ENERGY REQUIREMENTS, AND RETAIL VALUE OF THE BOVINE CARCASS

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