CHARACTERISTICS OF PRE-RIGOR PROCESSED BEEF

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Master of Science

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by

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The undersigned, appointed by the Dean of the Graduate Faculty, have examined a thesis entitled

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CHAPTER I

INTRODUCTION

During the last 25 years, the total production of beef and beef products in the U.S. has markedly increased. Most of this increase has been in the form of ground beef and ground beef products (Sink, 1980). In 1970, 20 percent of the beef consumption was in the ground form, while in 1979 this percentage rose to 45 percent and is expected to reach 60 percent in the early 1980's (Nusbaum, 1979). This rise in ground beef consumption reflects the changing eating habits of the American people. It was projected that in 1980 about half of the meals would be consumed outside the home. The growth of the hotel, restaurant and institution (HRI) segment of beef marketing is another aspect of this phenomenon (Anon., 1978). The availability of this rather inexpensive and highly nutritious food commodity was based, mainly, on two production factors: cheap grain and cheap and abundant energy. Currently, the shortage in world grain production will likely increase grain exports, thus decreasing the availability of grain for livestock. The worsening energy crisis affects beef production in two ways, indirectly when grain is used by the chemical industry and for fuel production, and directly when energy is considered as an input in beef production.

The energy factor also influences the industrial segment of beef production. Conventional beef processing is an energy intensive operation with slow turnover of inventories. Tenderness, the most desirable beef quality characteristic, is improved by the chilling of the carcasses for 10 to 14 days, at relatively low temperatures (0 to 2 C). The process implies the existence of large inventories and therefore, large refrigeration facilities are needed.

A better understanding of the postmortem muscle metabolism makes possible an alternative to the conventional processing of beef. The boning of the carcass prior to chilling, namely hot boning, combined with appropriate conditions of temperature and holding time for the resulting cuts, makes possible in theory a product of similar quality to conventionally processed beef. Advantages in reduced refrigeration space and energy requirements are derived from handling only edible portions of meat (Henrickson, 1975). This method seems to be particularly suitable in the preparation of ground beef since the product is already mechanically tenderized. Cow beef is mainly fabricated in the ground form and is a relatively steady component of the overall beef supply. If the current trends in meat consumption and economic factors are maintained, more short fed and less highly finished beef will likely be produced.

In view of these considerations, the objectives of this study were:

1. To compare pH, water holding capacity, shear force values, cooking and sensory characteristics of boneless beef rib

roasts processed from pre-rigor cow carcasses (hot boned) and post-rigor carcasses.

2. To compare microbiological quality, proximate composition, color, pH and water holding capacity of:
   (a) ground beef prepared from pre-rigor carcasses (hot boned);
   (b) ground beef prepared from pre-rigor carcasses with added salt;
   (c) ground beef prepared from post-rigor carcases.
3. To compare the effect of cooking methods, microwave oven and conventional gas oven, on the physical and sensory characteristics of ground beef prepared in Objective 2.

CHAPTER II

REVIEW OF LITERATURE

Postmortem Changes in Muscle

The conversion of muscle into meat implies physical and biochemical changes. After slaughter, under anaerobic conditions, muscle suffers a loss of extensibility and a decrease in pH. These phenomena are linked to the depletion of adenosine triphosphate (ATP) levels, the conversion of glycogen into lactic acid and the formation of the protein complex, actomyosin. In this complex, the sliding mechanism of the former elastic actin and myosin is locked. The entire process, toward the onset of rigor mortis--the stiffening of meat--has two phases: a first, which proceeds slowly, the delay period, followed by a second, which increases its rate, the fast phase. At the end of the process the muscle has lost its extensibility and its ATP reserves are depleted (Bendall, 1973).

Commercial practices in conventional meat processing chill the carcasses soon after slaughter, with a two-fold purpose: control of bacterial growth which can lead to spoilage, and to minimize weight losses through moisture evaporation while the carcasses are still hot. This practice often results in the toughening of the meat. Locker and Hagyard (1963) related this toughening with a cold shortening effect,

dependent on the temperature. They found that muscles shortened more at 2 C than at 37 C, with a minimum shortening in the range 14 - 19 C. They reported that shortening coincided with the onset of rigor mortis at higher temperatures but it began rapidly at low temperatures (0 - 2 C). Davey et al. (1967) reported that toughness increased four to five times when shortening of sarcomeres varied from 20 to 40 percent of their initial length, with a sharp decline in toughness with further shortening of sarcomeres from 40 to 50 percent. Cassens and Newbold (1966) studied the effects of temperature on postmortem metabolism of excised bovine sternomandibularis muscle. They found that changes in pH fall and decreases of creatine phosphate occurred more slowly at 15 C than at 37 C and that the time needed to reach the ultimate pH was longer with lower temperatures in the range 37 - 1 Celsius. The delay phase of rigor mortis was longer with temperature within 37 - 15 C, and shorter with lower temperatures within 15 - 1 C, while the onset phase was longer with temperatures within 37 - 5 C and shorter at 1 C than at 5 C. The acid labile phosphorus was at a low level at 37 C when the changes in extension of muscle were complete, and the pH was at its ultimate value. However, at 1 C, the acid labile phosphorus level was higher than at 37 C, the pH was above the ultimate value, and cold shortening, as well as thaw contracture occurred (Cassens and Newbold, 1967). Davey and Gilbert (1974) explained the cold shortening phenomenon by a buildup of Ca^{2+} ions discharged from the sarcoplasmic reticulum (SR) in the myofibrils. The fact that cold shortening occurred at 1 C and not at 15 C was

attributed to the inability of the SR to retain high concentrations of Ca^{2+} at low temperatures (Cornforth et al., 1980). Greaser (1974) attributed the shortening at high temperatures to the reduced ability of the SR to accumulate Ca^{2+}, when muscle temperature is above 25 C, during the first hours postmortem.

Glycolysis and Temperature

Glycolytic rate during chilling varies between muscles and within muscles. Rate of glycolysis increases with depth in muscle, as a consequence of the different temperatures caused by the loss of heat. Tarrant and Mothersill (1977) reported a positive correlation between rate of ATP turnover and muscle temperature in the range 38 - 7 C. Davey and Gilbert (1976) have shown that disappearance of ATP is accelerated over the latent heat phase of ice and is completed during frozen storage at 12 C. At these temperatures, glycolysis is stopped and ATP disappearance is attributed to enzymic activity. Pierson and Fox (1976) reported a more rapid decline of pH fall in longissimus muscle at 3 C than at 20 C and according to Jeacocke (1977), the rate of pH fall was minimum between 10 - 12 C and increased when cold shortening occurred. This phenomenon was attributed to an increased activity of ATP-ase stimulating glycolysis acting over the contractile actomyosin.

These complex biochemical changes, which involve parameters such as phosphocreatine, ATP, lactate and pH, can be related one to another. Variations between these parameters are not affected by

changes in muscle temperature. They are important during rigor process, chilling and freezing, and a simple measurement of pH can indicate if the muscle will shorten if chilled (Bendall, 1979).

Glycolysis is an exothermic reaction. Morley (1974) measured total heat production during rigor mortis in isolated muscle. The rate of heat production gave a mean value of 1.5 K Joule/Kg hour, during 4.5 hours postmortem. This heat liberated inside the carcass, plus the heat content, must be removed by refrigeration to avoid spoilage.

Hot Boning

In a broad sense, hot boning (HB) consists of the excision of muscle from the carcass in a pre-rigor state. Several workers have reported on the feasibility of the pre-rigor processing of pork carcasses into hams (Mandigo and Henrickson, 1966; Davidson et al., 1968), cured canned muscles (Gopal Reddy and Henrickson, 1969), fresh pork sausage (Hwei et al., 1979; Davidson et al., 1968), and frankfurters (Stilwell, 1978). The hot cutting of lambs was investigated by McLeod et al. (1974). The hot cuts were shrink wrapped, packed in cartons and stored at 1 C. After 12 hours, the meat in cartons reached temperatures where cold shortening occurs, but at that time the meat was near the onset of rigor. Toughening was observed in muscles of legs with their lateral face against the wall of the box. Also, some problems were observed during cutting operations due to the soft state of the pieces. They suggested electrical stimulation as a way to

get early onset of rigor and brief pre-chilling to harden the fat and meat to help in the cutting operations and avoid problems due to change of cut shape.

Most of the research done in HB beef has consisted of varying the conditions of holding time and temperature between slaughter and boning, and conditioning time and temperature for the cuts before they are chilled or frozen (Table 1). Schmidt and Gilbert (1970) reported different responses from bovine muscles excised 2 hours after slaughter and stored for 24 and 48 hours at 15 C. Positive results on tenderness were observed for biceps femoris, anterior longissimus and posterior longissimus, while semitendinosus samples were tougher than control samples held 48 hours in the carcass. This was attributed to the restrained position of this muscle in the carcass. Kastner et al. (1973) reported that steaks from sides held 8 hours at 16 C and then hot boned, were equal or superior to steaks from sides chilled 48 hours at 2 C and then cold boned, for the following characteristics: shrink (percent loss), shear force, color rating, flavor, cooking loss, water binding capacity, percent moisture, and fat. Shorter conditioning periods, 2 and 5 hours, were considered not satisfactory. On the contrary, Will et al. (1976) studied similar characteristics of bovine biceps femoris, longissimus and semimembranosus muscles held in sides for three delayed chilling periods (3, 5, and 7 hours) at 16 C before fabrication, and then stored at 1.1 C until 48 hours postmortem. No major differences were observed in objective and subjective tests when the characteristics of the early excised muscles were compared with

TABLE 1

TIMES AND TEMPERATURES USED IN HOT BONING

Author(s)	Holding Time Before Boning (hours)	Temperature (C)	Observations	Conditioning Time for Primal Cuts (hours)	Temperature (C)	Storage Time (days)	Temperature (C)
Corte et al. (1980)	3 or 4	---	ES, boxed	2	---	5	2
Cross & Tennet (1980)	1 or 4	---	ES and NS	---	---	---	---
Dransfield et al. (1976)	3	---	---	24	10	6 or 10	1
Gilbert et al. (1977)	2	---	ES, boxed	---	---	2	5
Kastner et al. (1973)	2, 5, or 8	16	---	up to 48	2	---	---
Ray et al. (1980)	1.5	---	ES, pH 6.4	---	---	---	---

TABLE 1, continued

Author(s)	Holding Time Before Boning (hours)	Temperature (C)	Observations	Conditioning Time for Primal Cuts (hours)	Temperature (C)	Storage Time (days)	Temperature (C)
Schmidt & Gilbert (1970)	2	---	VP	24 or 48	15	---	---
Seideman et al. (1979)	1	---	ES, VP	---	---	15	1+1
Strange & Benedict (1978)	0.7	---	---	4 or 6	20	up to 20	3
Tarrant (1977)	1	---	---	23	10	24	3
Taylor et al. (1981)	1 or 2	---	VP	{9 / 18}	{10 / 1}	5 or 21	1
	1 or 2	---	ES, VP	21	1	5 or 21	1
Will et al. (1976)	3, 5, or 7	16	---	41, 43, or 45	1.1	---	---

NOTE: ES--Electrically stimulated; NS--Non-stimulated; VP--Vacuum packed.

those of muscles held in sides for a full period of 48 hours at 1.1 C. Dransfield et al. (1976) reported an increase of 10 percent in toughness of muscles removed 3 hours after stunning, held at 10 C until 24 hours postmortem and finally stored for six or ten days at 1 C. Subsequent aging reduced the toughness in the hot boned muscles in the same proportion as in the control conventionally processed muscles. Cooking losses were unaffected by hot boning.

Special attention has been given to the relationship between pH fall and glycolytic rate in HB operations. Follet et al. (1974) studied the ante-rigor excision and air cooling of beef semitendinosus muscle at temperatures between -5 and +15 C. The variation in temperature according to the depth in excised muscle was reduced compared to the temperature gradient of the paired muscles in the carcass. This reduction was translated in a retardation of the biochemical changes (pH fall, ATP turnover, lactate accumulation) during cooling. Beneficial effects on tenderness and drip loss were accomplished by holding muscles between +5 and +15 C, while those held at -5 C yielded a tougher meat than those conditioned in the carcass at 0 $\pm$ 1 C. These results are in agreement with those reported by Tarrant (1977) for semitendinosus muscle. Temperature and pH were measured at different depths of excised muscles held at 10 C and in carcass muscle held at 3 C. In excised muscle, the rate of pH fall was more uniform than in the carcass, and ultimate pH was reached in 24 hours, while in the carcass it was reached between 6 and 48 hours, depending on the depth in muscle. In the carcass two situations occurred with adverse

consequences for meat quality: in the deep points, with temperatures above 30 C, rapid glycolysis produced pH below 6.0, conditions associated with protein denaturation and decreased water holding capacity, while in more superficial layers of the carcass (1.5 cm depth) low temperatures, below 10 C, and high pH, above 6.0, occurred simultaneously between 10 and 14 hours postmortem, situations associated with cold shortening and toughening of the meat.

Electrical Stimulation and Hot Boning

Electrical stimulation (ES) has been proposed as a solution to the contradictory need for early chilling to retard bacterial growth and delay chilling to avoid toughness of meat when pre-rigor carcasses are exposed to cold temperatures. The carcasses are subjected to electrical impulses, which cause violent contractions of the muscles, a rapid depletion of the ATP, and a rapid acceleration of pH decline in the muscle (Carse, 1973; Chrystall and Hagyard, 1975), allowing quick chilling without danger of cold shortening or thaw contracture (Bendall, 1976). The method was proposed for the first time by Harsham and Deatherage in 1951 (Deatherage, 1980). Subsequent research and development to an industrial scale was performed in New Zealand, making possible the early chilling of lamb carcasses without risk of cold shortening (Chrystall and Devine, 1980). Currently the practice of ES has been extended to beef.

Researchers working in this field have used different values for voltage, frequency, pulse duration and stimulation period (Table 2). A systematic study of the influence of these electrical parameters in

TABLE 2

PARAMETER VALUES USED IN ELECTRICAL STIMULATION

Author(s)	Stimulation Time Postmortem (minutes)	Voltage (volts)	Frequency (pulses/sec)	Stimulation Period
Bouton et al. (1980)	60-120	1,100	400	---
	---	110	---	15 min
Carse (1973)	30-40	45	---	---
Corte et al. (1980)	30	700	60	2-15 min
	30	300	---	---
Davey et al. (1976)	30	1,600	15	10 sec-10 min
George et al. (1980) & Taylor et al. (1981)	50	700	25	4 x 30 sec
Savel et al. (1978)	60	440	50-60	50 x .05 sec
	---	---	---	50 x 1 sec
Shaw and Walker (1977)	35	<120	---	---
	6-11	21	---	---

the biochemical changes of muscle, measured in terms of pH fall (ΔpH) and rate of pH fall (dpH/dt) was made by Chrystall and Devine (1978). Although a functional nervous system is not essential in order to effect ES (Devine et al., 1979), response is affected by delay in application and voltage (Chrystall et al., 1980), the later apparently the most important among the electrical parameters involved in ES (Carse, 1973; Shaw and Walker, 1977).

The extent and the rate of pH fall (ΔpH and dpH/dt) produced by ES in the carcass are of practical importance to the meat processor because these two parameters determine the time that muscle needs to reach a pH of 6.0, when muscle can be exposed to temperatures below 10 C without risk of cold shortening. In case of freezing, more time of conditioning is required to avoid thaw shortening upon subsequent thawing (Chrystall et al., 1980).

Effect of Electrical Stimulation on Hot Boned Meat Characteristics

Color. According to Cross and Tennet (1980), early boning gave darker muscles than those removed 48 hours postmortem due to difference in temperature and pH in muscle at the time of boning. Taylor et al. (1981) compared two HB processes, ES and non ES, against conventional processing. HB meat produced less drip and a more even color than the cold processed one. The effect was less when HB was preceded by ES. In that case, greater drip and paler color were observed in joints which were the last to be removed from the carcass, suggesting that

early pH fall increased protein denaturation and emphasizing the importance of early boning.

Cooking losses. Seideman et al. (1979) reported that ES HB and vacuum packaged sternomandibularis muscles had lower losses during storage but higher losses during cooking than those values from muscles conventionally handled. According to Cross and Tennet (1980), cooking losses tended to increase with postmortem boning time. ES had no significant effect on water holding capacity of meat.

Texture and sensory characteristics. The reviewed literature contains contradictory reports in regard to the effect of electrical stimulation on texture and sensory characteristics. Negative effects on tenderness and changes of shape were reported by Ray et al. (1980) while several other researchers reported improved tenderness (Chrystall and Hagyard, 1975; Gilbert and Davey, 1976; Davey et al., 1976; and Corte et al., 1980). No difference in tenderness was reported by Gilbert et al. (1977) when ES, HB beef primal cuts, boxed, and chilled or frozen, were compared with cuts from conventionally chilled sides. According to Seideman et al. (1979) no effect was detected from the ES and HB treatment on tenderness, flavor, desirability, pH, and sarcomere length. Taylor et al. (1981) compared HB, ES HB, and cold boned beef, all processed in conditions designed purposely to avoid cold shortening. They reported no differences in texture with the treatments. HB in these conditions did not affect juiciness, flavor or texture and there was no indication of any tenderizing effect from ES.

George et al. (1980) suggested that the higher temperatures observed in muscles of ES sides were likely to affect the tenderizing effect and, in agreement with Taylor et al. (1981) concluded that to achieve an improvement in tenderness, ES treatment must be accompanied with appropriate postmortem cooling regimen.

Effect of Mincing on Pre-rigor Muscle

Fabrication of pre-rigor muscles directly into ground products without prior chilling is of interest to meat processors because of the energy savings and high water holding capacity of the pre-rigor muscle, a fact well known by old sausage manufacturers. Most of the limited literature published on the subject has been done in Germany (Hamm, 1977).

Newbold and Scopes (1971) reported that grinding of pre-rigor muscle caused an increase by three-fold in ATP-ase activity and glycolytic metabolism. Hamm (1977) attributed this increase in ATP turnover at 4 C to the damage in the sarcoplasmic reticulum (SR) of the muscle cell, with the subsequent release of Ca^{2+} ions which activate myosin ATP-ase. According to Honikel and Hamm (1978), the rate of ATP and glycogen breakdown from 24 C to around 6 C follows the pattern of the enzymatic reactions influenced by temperature, namely the decrease of the reaction rate with decreasing temperatures. But the observation that in the range from 6 C to -1 C grinding causes an increase in ATP turnover suggests that the Ca^{2+} pump is still effective in the minced tissue. At these low temperatures (below 6 C) the Ca^{2+} pump of the SR loses its ability to keep concentration of calcium ions

low around the myofilaments. The increase in rate of ATP turnover reaches a maximum at -1 C, at which temperature (latent heat phase of water freezing in meat) the meat remains until it is completely frozen (Honikel and Hamm, 1978). If the meat is frozen quickly, it is possible to conserve during several weeks a ground meat with high water holding capacity to be used directly from the frozen state, without thawing, in the manufacture of sausages.

Effect of Sodium Chloride on Minced Pre-rigor Muscle

Addition of sodium chloride to minced meat causes a shift in the isoelectric point of muscle proteins to lower pH values, resulting in an increase in water holding capacity (WHC) of meat (Hamm, 1960). Less drip after thawing and high WHC in meat salted before freezing was reported by Wierbicki et al. (1957). The addition of a neutral salt, KCl, to pre-rigor bovine muscle caused a more rapid loss of ATP, but glycolysis ceased earlier and the ultimate pH was higher than in the unsalted minced muscle (Newbold and Scopes, 1971). According to Hamm (1977), the inhibition of glycolysis by NaCl after 6 - 9 hours postmortem is due to the effect of low pH and high ionic strength, both factors affecting the denaturation of enzyme proteins. Enzyme inhibition occurs at a higher pH (5.8) in the presence than in the absence of salt (pH ~ 5.5). The high WHC of salted pre-rigor meat was explained by the prevention of the onset of rigor mortis in the fiber fragments by a strong electrostatic repulsion of adjacent protein molecules caused by a combination of ATP, high ionic strength and high

pH. Honikel and Hamm (1978) reported that the rate of ATP breakdown and lactate formation in salted pre-rigor muscle homogenate decreased continuously with decreasing temperatures until the tissue was completely frozen. The higher ATP turnover in salted tissue at temperatures above 3 C was explained by an exchange of Ca^{2+} ions from the SR against Na^{+} ions from the added salt. These released Ca^{2+} ions activate the myosin ATP-ase. If most of the Ca^{2+} ions have been released from the SR at higher temperatures, no more Ca^{2+} ions remain to produce a "cold shortening" effect when the tissue reaches temperatures below 6 C (Honikel and Hamm, 1978).

Jolley et al. (1981) suggested that in order to obtain a high WHC, meat should be salted prior to the onset of rigor. Temperatures of storage should be chosen to induce a low rate of ATP turnover, to allow more flexibility in the operations between slaughter and salting. The range 5 - 15 C would be compatible with microbiological considerations.

Microbiology

Several researchers have reported information about microbial quality of hot boned meat. Schmidt and Gilbert (1970) reported bacterial counts of 10^2 - 10^5 microorganisms/cm^2 in muscle surface after 48 hours at 15 C in vacuum packages. Gilbert and Davey (1976) and Taylor et al. (1981) reported that bacterial condition was unaffected by stimulation or early boning. Kastner (1977) pointed out improved sanitation and shelf life as one of the potential advantages of hot boning, due to rapid processing, vacuum packaging and early

chilling. Nevertheless, in hot boned meat one might expect changes in number and composition of the microbial flora usually found in conventionally processed meat. According to Kotula and Emswiler-Rose (1981) both the initial and final (after 20 days of storage) aerobic plate counts at 20 and 35 C were greater for hot boned vacuum packaged beef primal cuts than for cold boned primals. The reduction in surface water activity by desiccation during carcass chilling was suggested as a factor in destruction of mesotrophic bacteria. The surface of vacuum packaged hot boned meat did not desiccate because the moisture loss was prevented by the packaging material. Strange and Benedict (1978) also reported a higher initial bacterial count for hot boned meat stored at 3C, wrapped in oxygen permeable-water impermeable film, than for cold boned meat, but after 10 days of storage, the cold boned meat counts were higher than that of hot boned meat. Initially, bacteria of the mesophilic type (catalase positive, gram positive, cocci) were predominant, but as time of storage at refrigerator temperature increased, these bacteria were replaced by the usual meat spoilage organisms (gram negative, catalase positive, short rods) with the characteristic odor of Pseudomonas.

Temperature is the most important single factor affecting microbial growth, in a range of -5 to 70 C, and generation time depends directly on temperature (Mossel and Ingram, 1955). Follet et al. (1974) found a progressive increase in bacterial counts for meats held from -5 to 15 C. Gill and Newton (1977) investigated the aerobic spoilage flora on meat slices. In a range from 2 to 15 C, Pseudomonas

grew faster than other species, with generation times about 4 times shorter at 15 than at 2 C.

Higher mesophilic and psychrophilic counts were also reported for hot processed ham than for cold processed ham after 15 and 20 days (Davidson et al., 1968). Hwei et al. (1979) reported that pre-rigor pork sausages stored at 2 - 5 C had higher total aerobic mesophiles and lypolytic bacterial counts than sausages from post-rigor meat.

The bacterial quality of ground beef from hot boned carcasses was equal or better than ground beef from chilled carcasses, according to Emswiler and Kotula (1979). Further, no differences of any practical importance were observed in most probable number of coliforms and *E. coli*.

A larger lag phase (1 day) was reported (Raccah and Henrickson, 1978) for electrically stimulated, hot boned ground beef, wrapped in polyvinyl chloride film and stored at 5 $\pm$ 1 C, than for conventionally processed ground product similarly displayed. "Off-odors" were detected after 4 - 5 days in control and after 7 - 8 days in hot processed samples. There was no difference in the composition of the flora for both hot and cold processed products.

CHAPTER III

MATERIALS AND METHODS

Experimental Units

Seven cows, Hereford, Angus, and Charolais, between 4 and 8 years of age, and with carcass weight between 230 and 265 Kg, were used for this study. The animals were slaughtered at the University abattoir and processed at the Meat Laboratory of the Department of Food Science and Nutrition, University of Missouri-Columbia, over a period of four months.

One forequarter from each carcass was hot boned within 1 - 2 hours postmortem, and the other forequarter remained intact in its side for a 6-day period stored in a 2 C cooler before being cold boned.

From both hot and cold boning treatments, boneless rib roasts and ground beef, salted and non-salted, were prepared.

Boneless Rib Roasts

The wholesale rib was removed from the forequarter, boned, shaped, and stored in a 2 C cooler for later analysis.

Ground Beef

After the boneless rib roasts had been removed, the rest of the forequarter was used for ground beef purposes. The boneless meat was

ground (Toledo Scale, Model 5323, 2 HP) first through a plate with 1.27 cm diameter holes and then through a plate with 0.32 cm diameter holes. For the preparation of the ground beef, one percent sodium chloride on a meat weight basis was added to 2 - 3 Kg of the coarse ground meat after the first grinding step. The meat was thoroughly mixed by hand and then reground through the 0.32 cm plate. After the separation of the quantities needed for immediate analysis and cooking trials of fresh ground beef, the rest was stuffed, directly from the grinder, using a horn, into polyethylene casings (8 cm in diameter). The filled casings were labeled and placed in a -27 C blast freezer until completely frozen and then stored at -23 C for subsequent analysis.

Boneless Rib Roast Analyses

Three different kinds of roasts were prepared. These three treatments were: hot boned, pre-rigor roasts (pH above 6.0); a post-rigor roast, taken from the rest of the hot boned rib, after a 48 hour period of storage at 2 C; and a cold boned (post-rigor) roast from the chilled forequarter.

pH Determination

Slices of the lean meat from the interior of the longissimus muscle from both hot boned pre-rigor and cold boned post-rigor roasts, were taken for pH determination, immediately before cooking of the roasts, with a Fisher Accumet® Model 320 expanded scale research pH meter, using a combination pH electrode Sensorex®.

Press Fluid Ratio Determination

The press method (Wierbicki and Deatherage, 1958) was used as an index of the water holding capacity of the meat. Quadruplicate samples of 300 - 400 mg of lean meat were taken from the interior of the longissimus muscle (from both pre-rigor hot boned and post-rigor cold boned rib roasts) immediately before cooking of the roasts. The samples were placed on 15 cm diameter No. 1 Whatman filter papers, of constant moisture content obtained by holding the filter paper in a dessicator, over saturated potassium chloride solution. The filter paper holding the meat sample was pressed between plexiglass plates for 5 min at 70.4 Kg/cm^2 on the ram of a hydraulic press (Carver®) (Thomas, 1972). The free moisture area and the meat film area were measured with a compensating polar planimeter. The reported dimensionless ratio was the free moisture area divided by the meat film area.

Cooking Procedure

One roast of approximately 1 Kg weight was cut for each of the three treatments. The roasts were cooked by microwave oven (Sharp®, Model R-6780, 2450 MHz, carrousel type). Initial and final internal temperatures, for control of degree of doneness, and roast weight before and after cooking for calculation of cooking losses, were taken and recorded. Total cooking time was divided into two heating power levels: first, four five-minute periods, one for each roast side, turning the roast over after each time, with the oven power control set on full power, for quicker and deeper heat penetration into the roast. Second, the oven power control was set on roast power until an internal

temperature of approximately 65 C was reached. After removal from the oven a 3 - 5 C increase was obtained as a result of temperature equilibration resulting in the final internal temperature of 68 - 70 C. Temperature was monitored with a digital thermometer OMEGA, 2166A, 10 channels and thermocouple probes. The cooked roasts were allowed to cool to approximately 40 C, weighed, vacuum packaged (Multivac®, type AGI, West Germany) into Cryovac® barrier bags, labeled, and put into a -27 C blast freezer until completely frozen and then stored at -23 C for subsequent sensory and shear force analysis.

Sensory Evaluation

The frozen roasts were removed from the -23 C storage and allowed to thaw 48 hours in a 2 C cooler. After that, the roasts were cut into 2.5 cm thick slices, across the fiber, and warmed in a gas oven to serving temperature. A six-member sensory panel evaluated the samples for juiciness, tenderness, flavor and overall acceptability (Figure 1). Samples from the three treatments, hot boned pre-rigor, hot boned post-rigor, and cold boned, were evaluated at the same time.

Objective Tenderness Evaluation

The Warner-Bratzler shear device was used to evaluate tenderness of cooked samples from the three treatments. Six cores of 1.27 cm in diameter were obtained from the 2.5 cm slice from each cooked roast, from the longissimus muscle. The results reported are the average of six values for each roast.

FIGURE 1

PANEL EVALUATION SHEET FOR COOKED BONELESS RIB ROASTS AND GROUND BEEF PATTIES

PALATABILITY SCORE SHEET

Judge_____
Sample #_____
Date_____
AM_____ PM_____

JUICINESS

1. Extremely dry
2. Very dry
3. Moderately dry
4. Slightly dry
5. Slightly juicy
6. Moderately juicy
7. Very juicy
8. Extremely juicy

TENDERNESS

1. Extremely tough
2. Very tough
3. Moderately tough
4. Slightly tough
5. Slightly tender
6. Moderately tender
7. Very tender
8. Extremely tender

FLAVOR

1. Extremely undesirable
2. Very undesirable
3. Moderately undesirable
4. Slightly undesirable
5. Slightly desirable
6. Moderately desirable
7. Very desirable
8. Extremely desirable

OVERALL ACCEPTABILITY

1. Extremely unacceptable
2. Very unacceptable
3. Moderately unacceptable
4. Slightly unacceptable
5. Slightly acceptable
6. Moderately acceptable
7. Very acceptable
8. Extremely acceptable

OTHER COMMENTS

Ground Beef Analyses

Three different kinds of ground beef were prepared from each of the animals: (1) hot boned ground beef, non-salted, (2) hot boned ground beef, 1 percent salt, and (3) cold boned ground beef, non-salted. Analyses for fat and moisture content, water holding capacity, pH, color, aerobic microbial plate count, sensory evaluation, and losses for cooking by both microwave and gas oven were performed for thawed patties cut from the frozen stuffed ground beef.

Fat Determination

The modified Babcock Fat Test (Terrell and Huffmann, 1969) was employed to determine fat content. The results reported are the average of duplicate determinations.

Total Moisture Determination

The air oven method (A.O.A.C., 1970) was used. Approximately 8 grams duplicate samples for each treatment were placed in pre-weighed, clean aluminum dishes and weighed to the nearest 0.001 grams. The dishes containing the samples were then dried with the lids removed in a forced hot air oven at 100 - 102 C for approximately 18 hours. After this, the dried samples were cooled in a dessicator with the lids on. The cool dried samples were weighed and the percent total moisture calculated from the loss of weight.

Press Fluid Ratio Determination

This analysis was performed in quadruplicate for each treatment, following the same procedure described previously.

pH Determination

Samples from each treatment were placed in a 50 ml beaker, homogenized with distilled water and the pH measured.

Color

Thawed patties were placed into polystyrene trays and wrapped in transparent, oxygen permeable film, and exposed to air for 1 hour at 2 C before the color was measured with a Hunter D25 Color Difference Meter. The results were expressed as lightness (L), yellowness (a) and redness (b), and are reported as the average of ten values from each sample.

Total Aerobic Microbial Count

Samples of thawed ground beef, for each treatment and for all the replicates, were subjected to standard plate procedure (American Public Health Association, 1958). The 11-gram sample from each treatment was blended with 95 ml of 0.1 percent peptone in distilled water for 1 minute in the mixing bowl of a Waring blendor at high speed. Difco standard plate agar was used for plating. The plates were incubated for 72 hours at 21 C and the counts were made using a Quebec colony counter. Averages of the counts for the duplicate plates were calculated and the results reported as logarithm of the colony forming units per gram of ground beef.

Cooking Procedures

For each of the seven replications of the three ground beef treatments, patties were prepared from the frozen ground beef by cutting

with a band saw into slices of 1.9 cm thickness. The patties were approximately 8 cm in diameter and weighed approximately 100 grams each, allowing uniformity in geometric parameters. For each treatment, the patties were wrapped individually in wax paper, packaged in groups of six, labeled and returned to the -23 C storage until 24 hours before the time to perform the required analyses, when they were placed in a 2 C cooler for complete thawing.

Microwave oven cooking. The microwave oven was the same used for cooking the roasts. Four thawed patties were cooked in the same circular tray each time, two per treatment, in order to have the same cooking conditions for patties later used for calculations of cooking losses and/or sensory evaluation.

As the cooking power of the microwave oven was observed to be very dependent on the oven load, when only two patties were cooked, the load was completed by placing in the same tray two plastic petri dishes containing 70 grams of water each.

Cooking was performed with the oven power control set on full power and alternating one minute-period of on-off.

Gas oven cooking. The oven used was a Wimco, forced air, natural gas, 105,000 BTU/hour, set at 176 C. Patties were cooked in groups of four or six, over a rack placed on a tray.

Degree of doneness. In both the microwave and gas oven cooking procedures the degree of doneness was monitored by thermocouple probes and digital thermometer as mentioned earlier for the roasts. In all

the cases, initial internal temperature was between 0 and 5 C and the final internal temperature was 68 - 70 C.

Cooking Losses

The difference in weight due to juice losses and evaporation was determined for both microwave and gas oven cooking procedure by weighing the patties individually before and after cooking. Results are the average of four values for fresh patties and of two values for frozen-thawed patties.

Sensory Evaluation

The six-member panel met 4 times a week, evaluating 4 or 6 samples each time. The patties were cooked immediately before being served, and attributes and scales were the same as used for the roasts.

Statistical Analysis

Analysis of variance (Snedecor and Cochran, 1967) was used to evaluate treatment differences. Correlation coefficients were computed between mean values of ground beef characteristics.

CHAPTER IV

RESULTS AND DISCUSSION

Characteristics of Raw Boneless Rib Roasts

pH and Press Fluid Ratio Values

Mean values for pH and press fluid ratios of hot and cold boneless rib roasts are given in Table 3. The pH value for the hot processed (pre-rigor) roasts was higher ($P < .001$) than the corresponding value for the cold boned (post-rigor) roasts. Consequently, the press fluid ratio value was lower ($P < .001$) for the pre-rigor than for the post-rigor meat. The high pH of the pre-rigor meat indicated that the muscles were potentially subject to a state of glycolysis at the beginning of cooking. Lowering the pH, from approximately 7.0 in living muscle, to 5.5 in rigor muscle, decreased muscle hydration markedly. The drop in water holding capacity is due to the breakdown of adenosine triphosphate (ATP) and to the pH decline when lactic acid is formed during glycolysis (Hamm, 1963). Variability on the duration of the rigor process, at constant temperature, is dependent on the energy reserves in the muscle at death (Bendall, 1973). The small standard deviation of the pre-rigor muscle pH, and the ultimate pH value of post-rigor muscle, indicated that all the five replicates used in this study had approximately the same initial energy reserves in the muscle.

TABLE 3

EFFECT OF PROCESSING METHOD ON pH AND PRESS FLUID RATIO OF BONELESS BEEF RIB ROASTS

Treatment	pH	Press Fluid Ratio
Hot	6.39[a] (0.12)	2.43[a] (0.33)
Cold	5.42[b] (0.05)	3.27[b] (0.45)

NOTE: Data within brackets are standard deviations.

[a,b]Means in the same column bearing different superscripts differ significantly ($P < .01$).

Characteristics of Cooked Boneless Rib Roasts

Physical and sensory characteristics of hot processed pre-rigor (10-day), hot processed post-rigor (2-day), and cold processed (6-day) boneless rib roasts are presented in Table 4.

Total Cooking Losses

Total cooking losses were similar for the three treatments. The difference in water holding capacity among the raw hot processed pre-rigor and the cold processed roasts was not reflected in cooking losses. Cia and Marsh (1976) reported lower cooking losses for the microwave oven cooked pieces of pre-rigor bovine sternomandibularis muscle (pH 6.8 - 6.4), compared to boiled cooked pieces, and attributed this difference to the shorter cooking time (1.5 min) when the microwave oven was used. But in that case the meat pieces were smaller (150 grams) than those used in the present experiment (1,500 - 2,500 grams). According to Bouton et al. (1976), cooking losses increased with longer cooking times, and sample size determined the rate of heating and had a major effect on cooking losses. Tarrant (1977) reported that in hot carcasses, a rapid decline of pH at high temperatures (above 30 C) decreased water holding capacity. The pre-rigor roasts used in the present experiment averaged 2,000 grams in weight, with an average cooking time of 42 minutes to raise the initial temperature of 30 $\pm$ 9 C to a final temperature of 69 $\pm$ 9 C. This slow rise in temperature during cooking likely caused an acceleration of glycolysis, and a drop in water holding capacity, possibly before the temperature had risen enough to produce protein denaturation.

Warner-Bratzler Shear Values

The effects of treatment on Warner-Bratzler shear values are presented in Table 4. Mean shear values decreased with increased time postmortem from 6 days (hot pre-rigor), 2 days (hot post-rigor), and 6 days (cold processed). The 0-day roast had a higher ($P < .05$) shear value than the 6-day roast. This is in agreement with Berry et al. (1981) who compared the effect of cooking method (steam, hot water and electric oven) on hot and cold boned beef roasts, and reported higher shear values for hot than for cold boned roasts, regardless of the cooking method employed.

During cooking of the pre-rigor roasts, an increase in thickness and changes in shape were observed, similar to changes reported by Ray et al. (1980). They also found hot boned roasts tougher than cold boned roasts, and suggested that the contraction of hot boned roasts was caused by heat rigor during cooking. The results obtained in the present study demonstrated that the apparent heat shortening of pre-rigor roasts had a greater effect on shear values than the apparent cold shortening had on the hot post-rigor roasts. According to Davey and Gilbert (1975), heat shortening produces toughness due to the increased overlapping of the thick and thin filaments, the greater frictional contact between fibers in the shortened cooked meat, and the greater number of possible links between fibers per unit of muscle length. Paul et al. (1952) related the low rates of heat penetration during roasting of beef with increasing toughness in the pre-rigor muscle. Tenderness or toughness, according to Deatherage (1963), is

TABLE 4

TOTAL COOKING LOSSES, WARNER-BRATZLER SHEAR VALUES AND SENSORY CHARACTERISTICS OF BONELESS BEEF RIB ROASTS

Treatment	Total Cooking Losses (percent)	Shear Values (lb/1.3 cm)	Sensory Panel Scores			
			Acceptability	Flavor	Tenderness	Juiciness
Hot pre-rigor	43.54 (8.44)	19.41[a] (7.90)	3.63 (0.75)	3.54 (0.75)	2.12[a] (1.05)	3.29 (1.24)
Hot post-rigor	43.00 (4.75)	13.12[a,b] (3.38)	3.79 (0.56)	4.00 (0.24)	3.58[a,b] (0.80)	3.79 (0.63)
Cold processed	43.80 (5.54)	10.16[b] (2.23)	4.58 (0.62)	4.62 (0.58)	4.42[b] (1.66)	3.96 (0.63)

NOTE: Data within brackets are standard deviations. The scale for sensory panel scores are presented in Figure 1.

[a,b]Means in the same column bearing different superscripts differ significantly ($P < .05$). Means without superscripts are not significantly different from each other ($P > .05$).

directly related to the protein structure of muscle and the denaturation, coagulation and hydrolysis of muscle proteins.

Sensory Characteristics

Mean values for acceptability, flavor, tenderness, and juiciness, as determined by sensory panel, are given in Table 4.

The effect of treatment on acceptability, flavor, and juiciness was not significantly different, although there was a trend toward larger values with increasing postmortem times (0 days, 2 days, 6 days). Mean values for tenderness were correlated with the objective determination of tenderness by the Warner-Bratzler device. The cold processed roasts were more tender ($P < .05$) than the hot processed pre-rigor roasts. This result is in agreement with that reported by Berry et al. (1981).

As in the case of shear values, there was a beneficial effect on sensory characteristics derived from the increased postmortem time elapsed: in the 2-day roast, even though heat shortening was not observed, there was likely a shortening effect produced both by exposure to low temperature (Locker and Hagyard, 1963), as well as by the loss of tension when muscles were excised from the carcass prior to rigor (Locker, 1960).

Characteristics of Raw Ground Beef

Mean values for selected characteristics of raw ground beef are presented in Table 5.

TABLE 5

EFFECT OF TREATMENT ON RAW GROUND BEEF QUALITY CHARACTERISTICS

Treatment	pH	Press Fluid Ratio	Moisture (percent)	Fat (percent)	SPC (log)	Hunter Color Difference Factors		
						L	a	b
Pre-rigor non-salted	5.50[a] (0.11)	4.42 (1.35)	68.89 (6.92)	12.30 (8.57)	3.92 (0.77)	32.62 (5.27)	15.62 (3.91)	10.17 (1.65)
Pre-rigor salted	5.84[b] (0.12)	3.03 (0.57)	69.57 (7.43)	9.35 (8.39)	3.80 (0.66)	30.17 (3.03)	14.68 (2.73)	9.54 (1.45)
Cold processed	5.62[c] (0.04)	3.65 (1.42)	69.20 (5.82)	11.82 (8.26)	3.89 (0.81)	30.70 (3.17)	14.01 (1.85)	10.10 (0.10)

NOTE: Data within brackets are standard deviations.

[a,b,c]Means in the same column bearing different superscripts differ significantly ($P < .05$).

pH

Differences ($P < .05$) among treatments for pH were observed. The pre-rigor processed salted ground beef had a higher pH value than the pre-rigor non-salted ground beef. This agrees with results reported by Newbold and Scopes (1971) and Hamm (1977). The cold processed ground beef had a higher pH value than the pre-rigor non-salted ground beef. This disagrees with Jacobs and Sebranek (1980), who reported a pH value .3 units higher for pre-rigor frozen ground beef patties than for post-rigor samples. Processing conditions differed in these studies, mainly in the time-temperature conditions during grinding and freezing operations. In the cited work of Jacobs and Sebranek, the coarse ground pre-rigor meat was chilled at 5 C, where according to Jolley et al. (1981), the rate of pH fall postmortem is minimal. After a second grinding the pre-rigor ground beef was formed into patties and frozen in a cryogenic tunnel, which allowed a rapid passage through the latent heat phase step, at which temperature (-1 C) the rate of ATP turnover is maximal (Honikel and Hamm, 1978). Under these conditions the frozen pre-rigor patties did not reach the ultimate pH while in the present study, through the 24-hour thawing period, they did. Nevertheless, a question remained about the difference ($P < .05$) in pH between pre-rigor and post-rigor non-salted patties.

Press Fluid Ratio

Even though the mean values of the press fluid ratio were not significantly different, the pre-rigor salted ground beef had the

lowest press fluid ratio value and the pre-rigor non-salted the highest. Thus, the press fluid ratio values were inversely correlated with the pH values. These results agree with those reported by Thomas (1972). The high water holding capacity of the pre-rigor meat was lost during grinding, freezing and thawing operations under the conditions used in the present study. The processing conditions which affected the glycolytic process were likely detrimental for the water holding capacity of the pre-rigor ground beef. The low press fluid ratio value of the pre-rigor salted ground beef demonstrated that the addition of one percent of salt during grinding of the pre-rigor meat was enough to maintain the high water holding capacity during all processing operations.

Proximate Composition

Moisture and fat percent mean values were similar for the three treatments. Fat was more difficult to separate from lean during trimming operations of the pre-rigor forequarter than it was with the chilled forequarter, an observation previously reported by Jacobs and Sebranek (1980). This difference was not reflected in the results due to the variability in fat content of the seven replicates, which ranged from 25 to 1 percent.

Microbiology

Mean log total plate count (TPC) per gram of ground beef is presented in Table 5. No significant differences among treatments were observed. The only differences noted on individual counts coincided

with accidents during slaughter operations, which resulted in increased TPC's for the post-rigor but not for the pre-rigor ground beef. Emswiler and Kotula (1979) reported that TPC's from hot boned ground beef were slightly lower or not significantly different from those of cold boned ground beef over a 45-day period of storage at 0 C. Field et al. (1977) did not find differences in bacterial quality of ground beef from plants of different size and different holding time of meat before grinding. The strict observance of sanitary practices in plant operations appeared to be the most important factor in microbial quality for ground beef.

The differences in pH and salt content among different treatments seemed to be too small to affect microbial counts. According to Gill and Newton (1977), among the dominant bacteria usually found in aerobic meat spoilage flora, all bacteria, except the Acinetobacter sp. grew at their maximum rates in meat juice medium at pH values between 5.5 and 7.0.

In regard to the salt content in ground beef, addition of one percent salt to meat with a moisture content of 60 - 70 percent would make an effective concentration of 1.7 - 1.4 percent salt in the aqueous phase of the ground meat. According to Banwart (1979), most normal organisms are inhibited by 3 to 10 percent salt in the aqueous phase.

Color

Mean values for Hunter Color-Difference factors are given in Table 5. Instrumental measurement of color did not result in

significant differences. Some differences were observed by subjective observations in particular samples, such as a darker or deeper red appearance of the pre-rigor salted samples than the pre-rigor non-salted ones. Salt content may also cause a small depression in the freezing point of the aqueous phase of the pre-rigor salted samples, which could explain the moister aspect of the salted samples in contrast to non-salted samples, which appeared lighter in color. At the end of the 24-hour thawing period salted samples were moist and completely thawed, while non-salted samples appeared dry and still partially frozen. The effect of salt on color intensity of meat has been reported previously (Acton and Saffle, 1969; Huffman et al., 1981). According to Jacobs and Sebranek (1980), the diffuse reflectance of pre-rigor and post-rigor patties was not significantly different. Romans et al. (1965) reported that redness of meat surface was increased significantly with increased marbling, due to contrast between lean and fat placed in juxtaposition. This agrees with observations made on individual samples in the present study.

Characteristics of Cooked Ground Beef

Cooking Losses

The mean values for total cooking losses of ground beef patties, expressed as a percent of thawed weight, are presented in Table 6. Pre-rigor salted patties cooked by microwave oven (MWO) had the lowest ($P < .01$) total cooking losses compared to all other processing treatments and the other cooking method. Pre-rigor salted

TABLE 6

EFFECT OF TREATMENT AND COOKING METHOD ON COOKING LOSSES OF GROUND BEEF PATTIES

Treatment	Total Cooking Losses		
	Gas Oven (GO) Cooked	Microwave Oven (MWO) Cooked	Mean GO and MWO Cooked
Pre-rigor non-salted	30.39[a,b] (5.21)	32.12[a] (6.19)	31.26[a]
Pre-rigor salted	22.94[a,d] (7.40)	13.94[b,e] (2.99)	18.44[b]
Cold processed	33.79[b] (6.35)	38.87[c] (2.67)	36.33[c]
Level of Significance	$P < .01$	$P < .05$	$P < .05$

NOTE: Data within brackets are standard deviations.

[a,b,c]Means in the same column bearing different superscripts differ significantly.

[d,e]Means in the same row bearing different superscripts differ significantly ($P < .01$).

patties cooked by gas oven (GO), also had lower ($P < .05$) total cooking losses compared to all other processing treatments and the other cooking method, except cold processed patties cooked by GO. When results from both cooking methods were combined for each treatment, salted patties had lower ($P < .05$) cooking losses than both pre-rigor non-salted and cold processed patties. Pre-rigor non-salted patties had lower ($P < .05$) cooking losses compared with cold processed patties. Pre-rigor salted patties were more bulky and suffered less changes in their original dimensions after cooked than patties from the other two treatments. In addition, pre-rigor salted patties cooked by either method had more cohesiveness than both pre-rigor non-salted and post-rigor patties, which appeared crumbly and grainy and had a trend to break apart. Pre-rigor salted patties tended to need a longer cooking time to reach the desired degree of doneness than patties from the other two treatments. This was due to the greater juice retention in salted patties. Cooking time was approximately 20 minutes for a 4- or 6-patty batch in the GO, and 5-6 minutes for a 4-patty batch in the MWO. In the GO, patties were heated by a combination of radiation and convection, while in the MWO heat was generated within the patties by electromagnetic waves. Thus, cooking time and heat production mode were two variables that likely affected both evaporative and juice losses, although no significant difference was detected in cooking losses when cooking methods were compared. Lower cooking losses and less configuration changes in pre-rigor patties than in post-rigor patties were reported by Nusbaum (1979) and Cross et al. (1979). Cross

and Tennet (1981) compared the effect of boning time on ground beef characteristics and concluded that the earliest boning time resulted in patties with less height shrinkage and less cooking loss.

The effect of salt and salt plus phosphate in fluid retention during processing of meat has been studied by several researchers. Pepper and Schmidt (1975) reported that hot boned beef formulated with salt had higher cooking yields than those formulated with salt plus phosphate or salted cold boned beef rolls, but binding strength of these salted hot boned rolls was low. On the contrary, Huffman et al. (1981) concluded that salt was a primary factor in the development of cohesiveness in hamburger patties made from post-rigor meat. They also reported about the synergistic effect on fluid retention of salt plus phosphate, as has been previously reported by Mahon (1961).

Sensory Panel Evaluation

Acceptability. The mean acceptability scores for ground beef patties, from all treatments and both GO and MWO cooking methods, are presented in Table 7. No significant difference from cooking method was detected for the ground beef treatments. Among treatments, pre-rigor salted patties from both GO and MWO cooking methods were more ($P < .05$ and $P < .001$, respectively) acceptable than pre-rigor non-salted or post-rigor patties. There was no significant difference on acceptability between pre-rigor non-salted or post-rigor patties. There was no significant difference on acceptability between pre-rigor non-salted and post-rigor patties cooked either by GO or MWO.

TABLE 7

EFFECT OF TREATMENT AND COOKING METHOD ON ACCEPTABILITY OF GROUND BEEF PATTIES

Treatment	Acceptability Scores		
	Gas Oven (GO) Cooked	Microwave Oven (MWO) Cooked	Mean GO and MWO Cooked
Pre-rigor non-salted	5.04[a] (0.62)	4.43[a] (0.75)	4.74[a]
Pre-rigor salted	6.33[b] (0.83)	6.27[b] (0.86)	6.30[b]
Cold processed	4.78[a,c] (1.06)	4.53[a,c] (0.44)	4.65[a]
Level of Significance	$P < .05$	$P < .001$	$P < .001$

NOTE: Data within brackets are standard deviations.

[a,b,c]Means in the same column bearing different superscripts differ significantly.

Flavor. The mean flavor scores for ground beef patties from all treatments and cooking methods are given in Table 8. When scores from the two cooking methods were combined for each treatment, pre-rigor salted patties had higher ($P < .01$) flavor scores than pre-rigor non-salted or post-rigor patties. Pre-rigor non-salted patties did not differ significantly from post-rigor patties. As for the GO cooked patties, pre-rigor salted patties had higher ($P < .05$) flavor scores than pre-rigor non-salted patties. Post-rigor patties did not differ significantly in flavor from both pre-rigor salted and pre-rigor non-salted patties. Within the MWO cooked patties, pre-rigor salted patties had higher ($P < .01$) flavor scores than both pre-rigor non-salted and post-rigor patties. Post-rigor patties scored higher than pre-rigor non-salted patties, although the difference was not significant.

Juiciness. The mean juiciness scores, from all treatments and cooking methods, are presented in Table 9. When juiciness scores from both cooking methods were combined for each treatment, pre-rigor salted patties had higher ($P < .001$) juiciness scores than pre-rigor non-salted or post-rigor patties. Juiciness scores for pre-rigor non-salted and post-rigor patties did not differ significantly. Within each cooking method, for GO cooked patties, pre-rigor salted patties scored higher ($P < .05$) than pre-rigor non-salted or post-rigor patties, and pre-rigor non-salted were juicier ($P < .05$) than post-rigor patties. For MWO cooked patties, pre-rigor salted patties

TABLE 8

EFFECT OF TREATMENT AND COOKING METHOD ON FLAVOR OF GROUND BEEF PATTIES

Treatment	Flavor Scores		
	Gas Oven (GO) Cooked	Microwave Oven (MWO) Cooked	Mean GO and MWO Cooked
Pre-rigor non-salted	5.24[a] (0.64)	4.52[a] (0.72)	4.88[a]
Pre-rigor salted	6.33[b] (0.80)	6.36[b] (0.53)	6.35[b]
Cold processed	5.38[a,b] (1.16)	5.22[a] (0.65)	5.30[a]
Level of Significance	$P < .05$	$P < .01$	$P < .05$

NOTE: Data within brackets are standard deviations.

[a,b]Means in the same column bearing different superscripts differ significantly.

TABLE 9

EFFECT OF TREATMENT AND COOKING METHOD ON JUICINESS OF GROUND BEEF PATTIES

Treatment	Juiciness Scores		
	Gas Oven (GO) Cooked	Microwave Oven (MWO) Cooked	Mean GO and MWO Cooked
Pre-rigor non-salted	4.97^{a} (0.77)	4.36^{a} (0.94)	4.67^{a}
Pre-rigor salted	6.50^{b} (0.61)	7.03^{b} (0.75)	6.76^{b}
Cold processed	3.89^{c} (1.22)	4.06^{a} (0.80)	3.97^{a}
Level of Significance	$P < .05$	$P < .001$	$P < .001$

NOTE: Data within brackets are standard deviations.

^{a,b,c}Means in the same column bearing different superscripts differ significantly.

received higher ($P < .001$) juiciness scores than pre-rigor non-salted or post-rigor patties, while the two later mentioned did not differ significantly.

Tenderness. The effects of treatment and cooking methods on tenderness are presented in Table 10. When tenderness scores from both GO and MWO cooking methods were combined, pre-rigor salted patties had higher ($P < .001$) tenderness scores than pre-rigor non-salted or post-rigor patties. Pre-rigor salted patties cooked by GO were more ($P < .01$) tender than pre-rigor non-salted and post-rigor patties cooked by the same method. As far as MWO cooked patties is concerned, pre-rigor salted patties were more ($P < .001$) tender than pre-rigor non-salted or post-rigor patties.

When scores from all treatments were combined within each cooking method, no difference of any significance for any of the sensory attributes tested was detected.

Correlation coefficients of cooking losses versus acceptability, flavor, juiciness and tenderness scores, for GO and MWO cooking methods, are presented in Table 11. Within each cooking method, tenderness, juiciness and acceptability scores were highly correlated with cooking losses, with correlation coefficients ranging from -.99 to -.95. Flavor scores were somewhat less correlated, with correlation coefficients ranging from -.91 to -.79.

Characteristics of "hot" and "chill" boned beef patties were studied by Thomas (1972). He reported that "hot" boned beef patties

TABLE 10

EFFECT OF TREATMENT AND COOKING METHOD ON TENDERNESS OF GROUND BEEF PATTIES

Treatment	Tenderness Scores		
	Gas Oven (GO) Cooked	Microwave Oven (MWO) Cooked	Mean GO and MWO Cooked
Pre-rigor non-salted	5.02[a] (0.82)	4.93[a] (0.72)	4.97[a]
Pre-rigor salted	6.44[b] (0.40)	6.78[b] (0.68)	6.61[b]
Cold processed	4.86[a] (0.71)	4.30[a] (0.86)	4.58[a]
Level of Significance	$P < .01$	$P < .001$	$P < .001$

NOTE: Data within brackets are standard deviations.

[a,b]Means in the same column bearing different superscripts differ significantly.

TABLE 11

CORRELATION COEFFICIENTS OF COOKING LOSSES VERSUS SENSORY PANEL ATTRIBUTES

Cooking Method	Tenderness	Juiciness	Acceptability	Flavor
Gas oven	-.976**	-.994**	-.993**	-.909*
Microwave oven	-.999**	-.985*	-.951**	-.795*

*Significant at .05 level of probability.

**Significant at .01 level of probability.

had reduced flavor and overall desirability compared to "chill" boned beef patties, with no differences in cooking losses or juiciness. These findings are in agreement with the results of the present study.

Pre-rigor patties were less ($P < .05$) tender than post-rigor patties, according to Nusbaum (1979), in disagreement with Cross et al. (1979), who reported that hot boned patties were more tender and juicier than cold boned beef patties. In the present study, pre-rigor patties were more tender than post-rigor patties, although the difference was not significant.

The addition of salt to post-rigor patties resulted in an increase in juiciness and flavor, according to Huffman et al. (1981), in agreement with results of the present study. Although the addition of salt was not done to post-rigor patties, panelists expressed their preference for the salted samples.

CHAPTER V

SUMMARY AND CONCLUSIONS

This investigation was undertaken to study the pre-rigor processing of boneless rib roasts and ground beef from cow carcasses. Boneless rib roasts were excised "hot," cooked pre-rigor (3 to 4 hours after slaughter) and post-rigor (48 hours after slaughter) and compared with roasts from conventionally processed carcasses (6 days after slaughter). Pre-rigor processed ground beef (2 hours after slaughter), salted and unsalted, was compared with conventionally processed ground beef (6 days after slaughter). Characteristics of ground beef, cooked by gas oven or microwave, were also examined and compared.

Pre-rigor processing affected some characteristics of roasts. Hot-boned pre-rigor roasts had higher ($P < .001$) pH values and lower ($P < .001$) press fluid ratios than conventionally processed roasts. Total cooking losses were similar for the three treatments. Warner-Bratzler shear values of hot pre-rigor roasts were higher ($P < .05$) than those of conventionally processed roasts. Pre-rigor processing did not significantly affect shear force values of roasts cooked post-rigor.

Sensory characteristics of roasts were affected differently by processing. The conventionally processed roasts were more ($P < .05$)

tender than the hot boned pre-rigor roasts. Although acceptability, flavor and juiciness were not significantly affected by processing, sensory panel scores increased as postmortem aging of roasts was increased.

Processing treatments affected characteristics of ground beef. Pre-rigor salted ground beef had higher ($P < .05$) pH and a lower press fluid ratio than either conventionally processed or pre-rigor unsalted ground beef. Conventionally processed ground beef had higher ($P < .05$) pH value and lower press fluid ratio than pre-rigor unsalted ground beef. Neither pre-rigor processing nor addition of salt to pre-rigor processed ground beef affected proximate composition, total bacteria count or color as measured by the Hunter Color-Difference meter.

Pre-rigor salted patties cooked by microwave had less ($P < .01$) total cooking loss than similar patties cooked by conventional gas oven broiling. Pre-rigor salted patties from both cooking methods had less ($P < .05$) total cooking loss than patties from the other two processing methods.

Sensory panel attributes of ground beef were affected by processing but not by cooking method. Sensory panel scores of pre-rigor unsalted and conventionally processed patties did not differ significantly. Pre-rigor salted patties were more ($P < .005$) acceptable, had more ($P < .01$) desirable flavor, were juicier ($P < .001$) and more ($P < .001$) tender than both pre-rigor unsalted and conventionally processed patties.

Under the conditions of the present study, the following conclusions were made:

1. Pre-rigor processing of boneless rib roasts compared to conventionally processed roasts had these effects:
   (a) roasts were less tender when cooked in a pre-rigor state,
   (b) no major effect on tenderness when cooked in a post-rigor state,
   (c) no effect on total cooking losses, and
   (d) no effect on sensory panel acceptability, flavor and juiciness.
2. Pre-rigor processing of ground beef compared to conventionally processed ground beef had these effects:
   (a) lower pH and higher press fluid ratio,
   (b) no effect on proximate composition, microbial quality and color,
   (c) no effect on total cooking losses when cooked by conventional gas oven broiling,
   (d) lower total cooking losses when cooked by microwave, and
   (e) no effect on sensory panel attributes.
3. Pre-rigor processing of ground beef with addition of one percent salt compared to conventionally processed ground beef had these effects:
   (a) higher pH and lower press fluid ratio,
   (b) no effect on proximate composition, microbial quality and color,

(c) lower total cooking losses when cooked either by conventional gas oven broiling or microwave, and

(d) increased acceptability, flavor, juiciness and tenderness.

4. Sensory panel attributes of ground beef were not affected by cooking method.

REFERENCES

REFERENCES

Acton, J. C. and Saffle, R. L. 1969. Pre-blended and pre-rigor meat in sausage emulsions. Food Technol. 23:367.

American Public Health Association. 1958. Meat and Meat Products--Recommended Methods for the Microbial Examination of Foods. Publications Office. APHA Inc., New York, pp. 110-114.

Anon. 1978. Beef marketing: issues and concerns. Meat Processing 17(10):134.

Association of Official Analytical Chemists. 1970. "Official Methods of Analysis," 11th ed. Association of Official Analytical Chemists, Washington, DC.

Banwart, G. J. 1979. "Basic Food Microbiology," pp. 613-614. AVI Publishing Co., Westport, CT.

Bendall, J. R. 1973. Post-mortem changes in muscle. In "The Structure and Function of Muscle," Vol. 2, Chapt. 5. Academic Press, New York and London.

Bendall, J. R. 1976. Electrical stimulation of rabbit and lamb carcasses. J. Sci. Food Agric. 27:819.

Bendall, J. R. 1979. Relations between muscle pH and important biochemical parameters during the post-mortem changes in mammalian muscles. Meat Sci. 3:143.

Berry, B. W., Ray, E. E. and Stiffler, D. M. 1981. Sensory scores and shear force values for beef roasts cooked either before or after chilling. J. Food Sci. 46:231.

Bouton, P. E., Ford, A. L., Harris, P. V. and Shaw, F. D. 1980. Electrical stimulation of beef sides. Meat Sci. 4:145.

Bouton, P. E., Harris, P. V. and Shorthose, W. R. 1976. Factors influencing cooking losses from meat. J. Food Sci. 41:1042.

Carse, W. A. 1973. Meat quality and the acceleration of post-mortem glycolysis by electrical stimulation. J. Food Technol. 8:163.

Cassens, R. G. and Newbold, R. P. 1966. Effects of temperature on post-mortem metabolism in beef muscle. J. Sci. Food Agric. 17:254.

Cassens, R. G. and Newbold, R. P. 1967. Effect of temperature on the time course of rigor mortis in ox muscle. J. Food. Sci. 32:269.

Chrystall, B. B. and Devine, C. E. 1978. Electrical stimulation, muscle tension and glycolysis in bovine sternomandibularis. Meat Sci. 2:49.

Chrystall, B. B. and Devine, C. E. 1980. Electrical stimulation developments in New Zealand. Proceedings 26th European Meeting of Meat Research Workers, p. 104.

Chrystall, B. B. and Hagyard, C. J. 1975. Electrical stimulation and lamb tenderness. N. Z. J. of Agric. Res. 19:7.

Chrystall, B. B., Devine, C. E. and Davey, C. L. 1980. Studies in electrical stimulation: post-mortem decline in nervous response in lambs. Meat Sci. 4:69.

Cia, G. and Marsh, B. B. 1976. Properties of beef cooked before rigor onset. J. Food Sci. 41:1259.

Cornforth, D. P., Pearson, A. M.and Merkel, R. A. 1980. Relationship of mitochondria and sarcoplasmic reticulum to cold shortening. Meat Sci. 4:103.

Corte, O. O., Cia, G., Picchi, V., Procknor, M. L. S. C. and Delazari, J. 1980. Electrical stimulation and hot boning of beef carcasses associated with chilling or freezing. Proceedings 26th European Meeting of Meat Research Workers, pp. 53-56.

Cross, H. R. and Tennet, I. 1980. Accelerated processing systems for USDA choice and good beef carcasses. J. Food Sci. 45:765.

Cross, H. R. and Tennet, I. 1981. Effect of electrical stimulation and post mortem boning time on sensory and cookery properties of ground beef. J. Food Sci. 46:292.

Cross, H. R., Berry, B. W. and Muse, H. D. 1979. Sensory and cooking properties of ground beef prepared from hot and chilled beef carcasses. J. Food Sci. 44:1432.

Davey, C. L. and Gilbert, K. V. 1974. The mechanism of cold induced shortening in beef muscle. J. Food Technol. 9:51.

Davey, C. L. and Gilbert, K. V. 1975. Cooking shortening and the toughening of beef. J. Food. Technol. 10:333.

Davey, C. L. and Gilbert, K. V. 1976. Thaw contracture and the disappearance of adenosine triphosphate in frozen lamb. J. Sci. Food Agric. 27:1085.

Davey, C. L., Gilbert, K. V. and Carse, W. A. 1976. Carcass electrical stimulation to prevent cold shortening toughness in beef. N. Z. J. Agric. Res. 19:13.

Davey, C. L., Kuttel, Helen and Gilbert, K. V. 1967. Shortening as a factor in meat aging. J. Food Technol. 2:53.

Davidson, W. D., Chipef, R. L., Meade, R. J. and Hanson, L. E. 1968. Post mortem processing treatment on selected characteristics of ham and fresh pork sausage. Food Technol. 22:722.

Deatherage, F. E. 1963. The effect of water and inorganic salts on tenderness. Proc. Meat Tenderness Symposium. Camden, New Jersey. Campbell Soup Company, p. 45.

Deatherage, F. E. 1980. Early investigations on the acceleration of post mortem tenderization of meat by electrical stimulation. Proceedings 26th European Meeting of Meat Research Workers, p. 2.

Devine, C. E., Chrystall, B. B. and Davey, C. L. 1979. Studies in electrical stimulation: effect of neuromuscular blocking agents in lamb. J. Sci. Food Agric. 30:1007-1010.

Dransfield, E., Brown, A. J. and Rhodes, D. N. 1976. Eating quality of hot deboned beef. J. Food Technol. 11:401-407.

Emswiler, B. S. and Kotula, A. W. 1979. Bacteriological quality of ground beef prepared from hot and chilled beef carcasses. J. Food Prot. 42:561-562.

Field, R. A., Schmith, F. C., Deane, D. D., Thomas, G. M. and Kotula, A. W. 1977. Sources of variation at the retail level in bacteriological condition of ground beef. J. Food Prot. 40:385.

Follet, M. J., Norman, G. A. and Ratcliff, P. W. 1974. The ante-rigor excision and air cooling of beef semimembranosus muscles at temperatures between -5^{o}C and +15^{o}C. J. Food Technol. 9:509.

George, A. R., Bendall, J. R. and Jones, R. C. D. 1980. The tenderizing effect of electrical stimulation of beef carcasses. Meat Sci. 4:51.

Gilbert, K. V. and Davey, C. L. 1976. Carcass electrical stimulation and early boning of beef. N. Z. J. Agric. Res. 19:429.

Gilbert, K. V., Davey, C. L. and Newton, K. G. 1977. Electrical stimulation and the hot boning of beef. N. Z. J. of Agric. Res. 20:139.

Gill, C. O. and Newton, K. G. 1977. The development of aerobic spoilage flora on meat stored at chill temperatures. J. of Appl. Bacteriology 43:189.

Gopal Reddy, S. and Henrickson, R. L. 1969. Quality of pre-chilled canned porcine muscles. Food Technol. 23:941-943.

Greaser, M. L. 1974. Sarcoplasmic reticulum and its possible role in post mortem muscle. Proceedings 27th Annual Reciprocal Meat Conference of the American Meat Science Association, p. 337.

Hamm, R. 1960. Biochemistry of meat hydration. In "Advances in Food Research," 10:355.

Hamm, R. 1977. Post mortem breakdown of ATP and glycogen in ground muscle: a review. Meat Sci. 1:15.

Henrickson, R. L. 1975. Hot boning. Proceedings of the Meat Industry Research Conference, AMIF, Arlington, VA, p. 25.

Honikel, K. O. and Hamm, R. 1978. Influence of cooling and freezing of minced pre-rigor muscle on the breakdown of ATP and glycogen. Meat Sci. 2:181.

Huffman, D. L., Cross, H. R., Campbell, K. J. and Cordray, J. C. 1981. Effect of salt and tripolyphosphate on acceptability of flaked and formed hamburger patties. J. Food Sci. 46:34.

Hwei-Shen, Lin, Topel, D. G. and Walker, W. H. 1979. Influence of pre-rigor and post-rigor muscle on the bacteriological and quality characteristics of pork sausage. J. Food Sci. 44:1055.

Jacobs, D. K. and Sebranek, J. G. 1980. Use of pre-rigor beef for frozen beef patties. J. Food Sci. 45:648.

Jeacocke, R. E. 1977. The temperature dependence of anaerobic glycolysis in beef muscle held in a linear temperature gradient. J. Sci. Food Agric. 28:551.

Jolley, P. D., Honikel, K. O. and Hamm, R. 1981. Influence of temperature on the rate of postmortem metabolism and water holding capacity of bovine neck muscles. Meat Sci. 5:99.

Kastner, C. L. 1977. Hot processing: update on potential energy and related economies. Proceedings of the Meat Industry Research Conference, pp. 43-51.

Kastner, C. L., Henrickson, R. L. and Morrison, K. D. 1973. Characteristics of hot boned bovine muscle. J. of Anim. Sci. 36:484.

Kotula, A. W. and Emwiler-Rose, B. S. 1981. Bacteriological quality of hot boned primal cuts from electrically stimulated beef carcasses. J. Food Sci. 46:471.

Locker, R. H. 1960. Degree of muscular contraction as a factor in tenderness of beef. J. Food Res. 25:304.

Locker, R. H. and Hagyard, C. J. 1963. A cold shortening effect in beef muscles. J. Sci. Food Agric. 14:787.

Mahon, J. H. 1961. Tripolyphosphate-salt synergism and its effect on cured meat volume. Proceedings of the 13th Research Conference. AMIP Circular No. 64, p. 59.

Mandigo, R. W. and Henrickson, R. L. 1966. Influence of hot processing pork carcasses on cured ham. Food Technol. 20:538-540.

McLeod, K., Gilbert, K. V., Fairbairn, S. J. and Locker, R. H. 1974. Further experiments on the hot-cutting of lamb. J. Food Technol. 9:179.

Morley, M. J. 1974. Measurements of the heat production in beef muscle during rigor mortis. J. Food Technol. 9:149.

Mossel, D. A. A. and Ingram, M. 1955. The physiology of the microbial spoilage of foods. J. of Appl. Bacteriology 18:233.

Newbold, R. P. and Scopes, R. K. 1971. Post-mortem glycolysis in ox skeletal muscle: effects of mincing and dilution with or without addition of orthophosphate. J. Food Sci. 36:209-214.

Nusbaum, R. P. 1979. Structural and palatability traits of ground beef hot boned, chilled and frozen muscle. Proceedings 32nd Annual Reciprocal Meat Conference of the American Meat Science Association, South Dakota State University, Brookings, SD, June 17-21.

Paul, P., Bratzler, L. J., Farwel, E. D. and Knight, K. 1952. Studies on tenderness of beef. I. Rate of heat penetration. J. Food Res. 17:504.

Pepper, F. H. and Schmidt, G. R. 1975. Effect of blending time, salt, phosphate and hot boned beef on binding strength and cook yield of beef rolls. J. Food Sci. 40:227.

Pierson, C. J. and Fox, J. D. 1976. Effect of post mortem aging time and temperature on pH, tenderness and soluble collagen fraction in bovine longissimus muscle. J. of Anim. Sci. 43:1200.

Raccah, M. and Henrickson, R. L. 1978. Storage stability and bacteriological profile of refrigerated ground beef from electrically stimulated hot boned carcasses. J. Food Prot. 41:957.

Ray, E. E., Stiffler, D. M. and Berry, B. W. 1980. Effect of hot boning and cooking method upon physical changes, cooking time and losses, tenderness of beef roasts. J. Food Sci. 45:769.

Romans, J. R., Tuma, H. J. and Tucker, W. L. 1965. Influence of carcass maturity and marbling on the physical and chemical characteristics of beef. II. Muscle pigments and color. J. Anim. Sci. 24:686.

Savell, J. W., Smith, G. C. and Carpenter, Z. L. 1978. Beef quality and palatability as affected by electrical stimulation and cooler aging. J. Food Sci. 43:1666.

Schmidt, G. R. and Gilbert, K. V. 1970. The effect of muscle excision before the onset of rigor mortis on the palatability of beef. J. Food Technol. 5:331.

Seideman, S. C., Smith, G. C., Dufson, J. R. and Carpenter, Z. L. 1979. Physical, chemical and palatability traits of electrically stimulated, hot boned, vacuum packaged beef. J. Food Prot. 42:651.

Shaw, F. D. and Walker, D. J. 1977. Effect of low voltage stimulation of beef carcasses on muscle pH. J. Food Sci. 42:1140.

Sink, J. D. 1980. Industrial modeling and output estimates of the ground beef industry. Food Technol., June 1980, p. 58.

Snedecor, G. W. and Cochran, W. G. 1967. "Statistical Methods," 6th ed. The Iowa State University Press, Ames, Iowa.

Stilwell, P. E., Mandigo, R. W., Weiss, G. M. and Campbell, J. F. 1978. Accelerated pork processing: frankfurter emulsion properties. J. Food Sci. 43:1646.

Strange, E. D. and Benedict, R. C. 1978. Effect of post-mortem times on beef storage quality. J. Food Sci. 43:1652.

Tarrant, P. V. 1977. The effect of hot boning on glycolysis in beef muscle. J. Sci. Food Agric. 28:927.

Tarrant, P. V. and Mothersill, C. 1977. Glycolysis and associated changes in beef carcases. J. Sci. Food Agric. 28:739.

Taylor, A. A., Shaw, B. G. and MacDougall, D. B. 1981. Hot deboning beef with and without electrical stimulation. Meat Sci. 5:109-123.

Terrell, R. N. and Huffman, D. L. 1969. Rapid fat and moisture tests. Auburn Univ. Coop. Ext. Serv. Cir., R-17, Auburn, Alabama.

Thomas, W. K., Jr. 1972. Effect of pre-rigor processing on characteristics of comminuted and whole beef muscle. M.S. Thesis, University of Missouri-Columbia, Columbia, MO.

Wierbicki, E. and Deatherage, F. E. 1958. Determination of water holding capacity of fresh meats. J. of Agric. Food Chem. 6(5):387.

Wierbicki, E., Cahill, V. R. and Deatherage, F. E. 1957. Effect of added sodium chloride, potassium chloride, calcium chloride, magnesium chloride and citric acid on meat shrinkage at 70°C and of added sodium chloride on drip losses after freezing and thawing. Food Technol. 11:74.

Will, P. A., Henrickson, R. L. and Morrison, R. D. 1976. The influence of delay chilling and hot boning on tenderness of bovine muscle. J. Food Sci. 41:1102-1106.

APPENDIX

ANALYSIS OF VARIANCE OF pH VALUES
OF RAW ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	1	2.35	2.35*
Error	8	0.07	0.01
Total	9	2.42	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF PRESS FLUID RATIO
OF RAW ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	1	1.78	1.78*
Error	8	1.25	0.15
Total	9	3.03	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF WARNER-BRATZLER SHEAR VALUES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	178.62	89.31 NS
Error	9	236.43	26.27
Total	11	415.05	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TOTAL COOKING LOSSES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	1.65	0.82 NS
Error	12	497.88	41.49
Total	14	499.52	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TASTE PANEL ACCEPTABILITY SCORES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	2.09	1.04 NS
Error	9	3.80	0.42
Total	11	5.88	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TASTE PANEL FLAVOR SCORES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	2.35	1.18 NS
Error	9	8.59	0.95
Total	11	10.94	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TASTE PANEL JUICINESS SCORES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	0.96	0.48 NS
Error	9	7.05	0.78
Total	11	8.01	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TASTE PANEL TENDERNESS SCORES OF ROASTS

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	10.77	5.39 NS
Error	9	13.51	1.50
Total	11	24.28	

NS--No significant difference.

ANALYSIS OF VARIANCE OF pH VALUES
OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	0.31	0.16*
Error	14	0.13	0.01
Total	16	0.44	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF PRESS FLUID RATIO
OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	6.33	3.16 NS
Error	16	22.64	1.41
Total	18	28.97	

NS--No significant difference.

ANALYSIS OF VARIANCE OF PERCENT FAT CONTENT
OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	31.28	15.64 NS
Error	16	1134.44	70.90
Total	18	1165.72	

NS--No significant difference.

ANALYSIS OF VARIANCE OF PERCENT TOTAL MOISTURE CONTENT OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	1.47	0.73 NS
Error	16	733.04	45.81
Total	18	734.51	

NS--No significant difference.

ANALYSIS OF VARIANCE OF L HUNTER COLOR-DIFFERENCE FACTOR OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	18.94	9.47 NS
Error	14	226.66	16.19
Total	16	245.60	

NS--No significant difference.

ANALYSIS OF VARIANCE OF a HUNTER COLOR-DIFFERENCE FACTOR OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	7.92	3.96 NS
Error	14	123.49	8.82
Total	16	131.41	

NS--No significant difference.

ANALYSIS OF VARIANCE OF b HUNTER COLOR-DIFFERENCE FACTOR OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	1.27	0.63 NS
Error	14	32.44	2.32
Total	16	33.71	

NS--No significant difference.

ANALYSIS OF VARIANCE OF LOGARITHMS OF TOTAL BACTERIA COUNT OF GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	0.04	0.02 NS
Error	16	8.99	0.56
Total	18	9.03	

NS--No significant difference.

ANALYSIS OF VARIANCE OF COMBINED TOTAL COOKING LOSSES OF GO AND MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	5	2383.85	476.77*
Error	32	949.50	29.67
Total	37	3333.35	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF COMBINED TASTE PANEL ACCEPTABILITY SCORES OF GO AND MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	5	22.77	4.55*
Error	32	19.46	0.61
Total	37	42.23	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF COMBINED TASTE PANEL FLAVOR SCORES OF GO AND MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	5	16.29	3.26*
Error	32	18.94	0.59
Total	37	35.23	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF COMBINED TASTE PANEL JUICINESS SCORES OF GO AND MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	5	53.39	10.68*
Error	32	24.21	0.75
Total	37	77.60	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF COMBINED TASTE PANEL TENDERNESS SCORES OF GO AND MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	5	29.36	5.87*
Error	32	16.50	0.51
Total	37	45.86	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TOTAL COOKING LOSSES
OF GO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	371.56	185.78*
Error	16	658.57	39.91
Total	18	1010.12	

*Significant ($P < .05$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL ACCEPTABILITY SCORES OF GO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	8.42	4.21*
Error	16	11.40	0.71
Total	18	19.82	

*Significant ($P < .05$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL FLAVOR SCORES
OF GO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	4.40	2.20 NS
Error	16	12.36	0.77
Total	18	16.76	

NS--No significant difference.

ANALYSIS OF VARIANCE OF TASTE PANEL JUICINESS SCORES
OF GO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	20.67	10.34*
Error	16	12.87	0.80
Total	18	33.54	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL TENDERNESS SCORES OF GO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	9.27	4.63*
Error	16	7.35	0.46
Total	18	16.62	

*Significant ($P < .01$) difference.

ANALYSIS OF VARIANCE OF TOTAL COOKING LOSSES
OF MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	2008.91	1004.45*
Error	16	310.94	19.43
Total	18	2319.85	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL ACCEPTABILITY SCORES OF MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	13.36	6.68*
Error	16	8.05	0.50
Total	18	21.42	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL FLAVOR SCORES
OF MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	10.00	5.50*
Error	16	6.59	0.41
Total	18	17.58	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL JUICINESS SCORES
OF MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	32.72	16.36*
Error	16	11.34	0.71
Total	18	44.06	

*Significant ($P < .001$) difference.

ANALYSIS OF VARIANCE OF TASTE PANEL TENDERNESS SCORES
OF MWO COOKED GROUND BEEF

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Treatment	2	19.98	9.99*
Error	16	9.15	0.57
Total	18	29.14	

*Significant ($P < .001$) difference.

VITA

Baldo Roman Mourthe was born October 23, 1943, in Santa Cruz, Bolivia. After graduating from high school, he attended Universidad Nacional del Litoral, Santa Fe, in Argentina, and Universidad Boliviana Gabriel Rene Moreno, in Santa Cruz, Bolivia, where he received a Bachelor of Science degree in Chemical Engineering (1979). In August, 1979, he enrolled in Graduate School at the University of Missouri at Columbia, where he received a Master of Science degree in Food Science (1981). Presently, he is a member of the Department of Chemical Processes at Universidad Boliviana Gabriel Rene Moreno, Santa Cruz, Bolivia.

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