1984

The Effects of Sex and Delayed Chill on the Biophysical and Organoleptic Properties of Intact and Restructured Beef Steaks

Bruce Colin Paterson

Follow this and additional works at: https://openprairie.sdstate.edu/etd

Recommended Citation

This Thesis - Open Access is brought to you for free and open access by Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. It has been accepted for inclusion in Electronic Theses and Dissertations by an authorized administrator of Open PRAIRIE: Open Public Research Access Institutional Repository and Information Exchange. For more information, please contact michael.biondo@sdstate.edu.
THE EFFECTS OF SEX AND DELAYED CHILL ON THE
BIOPHYSICAL AND ORGANOLEPTIC PROPERTIES OF
INTACT AND RESTRUCTURED BEEF STEAKS

BY

BRUCE COLIN PATERSON

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science
Major in Animal Science
South Dakota State University
1984
This thesis is approved as a credible and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

D.H. Gee
Thesis Adviser

A.W. Jones
Thesis Adviser

John K. Romans
Head, Department of Animal and Range Sciences
ACKNOWLEDGEMENTS

The author wishes to express his sincere appreciation to Dr. Dan Gee, Dr. Kevin Jones, Dr. William Costello and Dr. John Romans for their assistance, advice and encouragement in planning and conducting of this research and in the preparation of this thesis.

Special thanks is extended to fellow graduate students Roger Johnson and Dean Jaycox for their help and advice. The valuable assistance of the South Dakota State University Meat Laboratory personnel and lab technician Barb Schrag is noted.

The generous help of Dr. W. Lee Tucker with the statistical analysis is gratefully appreciated.

Acknowledgement is given to Carla Lovro for her talent and efforts in typing this manuscript.

The writer wishes to express his deepest appreciation to his wife, Kim, and his parents, Bill and Eileen, for their encouragement and support during the preparation of this thesis.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>5</td>
</tr>
<tr>
<td>A. The Effects of Sex On Growth, Carcass and Palatability Characteristics</td>
<td>5</td>
</tr>
<tr>
<td>Growth Characteristics</td>
<td>5</td>
</tr>
<tr>
<td>Carcass Characteristics</td>
<td>6</td>
</tr>
<tr>
<td>Palatability Characteristics</td>
<td>11</td>
</tr>
<tr>
<td>B. Restructured Meats.</td>
<td>15</td>
</tr>
<tr>
<td>Comminution Method</td>
<td>16</td>
</tr>
<tr>
<td>Particle Size</td>
<td>19</td>
</tr>
<tr>
<td>Meat Temperature</td>
<td>21</td>
</tr>
<tr>
<td>Mixing Time</td>
<td>23</td>
</tr>
<tr>
<td>Chemistry of Meat Binding</td>
<td>26</td>
</tr>
<tr>
<td>Role of Specific Proteins in Binding</td>
<td></td>
</tr>
<tr>
<td>Meat Protein</td>
<td>26</td>
</tr>
<tr>
<td>Salt as a Meat Additive</td>
<td>31</td>
</tr>
<tr>
<td>Phosphate Addition</td>
<td>33</td>
</tr>
<tr>
<td>Non-meat Proteins</td>
<td>36</td>
</tr>
<tr>
<td>Binding as a Heat Mediated Reaction</td>
<td>38</td>
</tr>
<tr>
<td>Effects of Additives on Palatability</td>
<td>39</td>
</tr>
<tr>
<td>Cookery Methods</td>
<td>41</td>
</tr>
<tr>
<td>Restructured Meat Color</td>
<td>41</td>
</tr>
<tr>
<td>Restructured Meat Storage</td>
<td>44</td>
</tr>
</tbody>
</table>
C. Hot Processing. ................................. 45
  Advantages. ................................. 46
  Disadvantages ............................. 48
  Tenderness. ................................. 49
  Temperature Conditioning .................. 51
  Hot Processing Systems .................... 57
  Restructured Products ..................... 60

METHODOLOGY. ................................. 61
  A. Experiment #1. ............................ 61
      Delayed Chilling ........................ 61
      Carcass Data ........................... 61
      Carcass Temperature .................... 62
      pH ...................................... 62
      R-Values ................................ 62
      Sarcomere Length ....................... 62
      Cook Losses and Warner-Bratzler Shear Tests. .................. 63
      Sensory Evaluation ...................... 63
      Statistical Analysis .................... 64
  B. Experiment #2. ............................ 65
      Meat Source ............................. 65
      Steak Preparation ....................... 65
      Proximate Analysis ...................... 66
      TBA Analysis ............................ 66
      Steak Color ............................. 66
      Cooking Procedures ...................... 67
<table>
<thead>
<tr>
<th>CHARACTERISTICS OF CONVENTIONALLY CHILLED AND PRERIGOR CONDITIONED BOVINE MUSCLE FROM INTACT AND CASTRATED MALES</th>
<th>91</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE EFFECTS OF SEX AND DELAYED CHILL ON THE BIOPHYSICAL AND ORGANOLEPTIC PROPERTIES OF CHUNKED AND FORMED BEEF STEAK</td>
<td>116</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>140</td>
</tr>
<tr>
<td>PROCEDURE 1: R-VALUE DETERMINATION</td>
<td>141</td>
</tr>
<tr>
<td>PROCEDURE 2: TBA DETERMINATION</td>
<td>143</td>
</tr>
<tr>
<td>PROCEDURE 3: COOK LOSS DETERMINATIONS</td>
<td>145</td>
</tr>
<tr>
<td>PROCEDURE 4: SARCOMERE LENGTH DETERMINATIONS</td>
<td>146</td>
</tr>
<tr>
<td>FIGURE 1: PALATABILITY SCORE SHEET</td>
<td>147</td>
</tr>
</tbody>
</table>
INTRODUCTION

Increasing worldwide demand for animal protein and growing pressure on the available cereal grains by an increasing world population make it imperative that beef production efficiency increase. However, consumers will continue to demand a quality product that is lean, boneless and free from excess fat. This trend will accelerate as the costs of production and ultimate cost to the consumer increases (Cross and Allen, 1982).

Presently, the intact male may offer potential in improving growth efficiency and providing a desirable product to the consumer. Research indicates that bulls utilize feed more efficiently, grow faster and produce a leaner carcass with more retail product than steers (Field, 1971 and Seideman et al., 1982a) However, Seideman et al. (1982a) also indicated that meat production from intact males has encountered strong resistance from packers because of more difficulty in slaughtering procedures, heavier carcass weights and lower USDA quality grades. Cross and Allen (1982) stated that intact male beef has not attracted packer acceptance due to an unsure consumer acceptance at the retail level because of differences in color, texture and fat distribution. In addition, cooked meat from young bulls is often less tender than steer beef.
The primary goal of the meat industry is to maximize the value and utilization of skeletal muscle meat. The average carcass yields approximately 30 percent primal cuts (rib and loin) for which there is a ready market with a minimum of processing labor. Unfortunately, these primal cuts are a stable commodity and competition limits the profits from these cuts. The remaining 70% of the carcass consists of cuts that are less tender, less palatable and generally less desirable. Some of these products are sold with a minimum of processing at a lower price, while cuts with a high percentage of connective tissue are further processed into ground beef, frankfurters and sausage. Increasing the value of these lower quality, less desired cuts has economically pressured the meat industry to develop a new technology.

Restructuring involves the use of less valuable cuts, reducing the particle size, mixing and forming these particles into a product resembling an intact muscle. In addition to the utilization of trimmings and lower quality cuts from the carcass, restructured processing offers other advantages. These include: (1) controlled size, weight and shape of each portion; (2) a boneless product; (3) formulation to specified compositional standards; (4) control of fat content; (5) possible protein, vitamin and mineral fortification; (6) convenience; (7) reduction of connective tissue;
(8) ability to differentiate product through various flavorings and seasonings; (9) control of texture; (10) intermediate value (priced between ground beef and intact steaks) and (11) excellent sensory characteristics (Ferren, 1972; Anon, 1973; Mandigo, 1974 and 1975; Farrington, 1975; LeMaire, 1978; Ockerman, 1979; Breidenstein, 1982).

The meat industry presently utilizes large, inefficient storage coolers for cooling carcasses rather than more efficient systems for cooling edible boneless meat. When these facilities are combined with the practice of chilling, reheating and recolling tons of product each day, the need for efficient processing systems becomes evident. It is this inefficiency which has led to hot processing (Henrickson, 1982).

Hot processing is the removal of bone and trim prior to chilling and it has several possible economic benefits: (1) removal of bone and trim prior to chilling which reduces the energy required to chill; (2) more rapid chilling; (3) decreased refrigeration space required; (4) reduced cooler shrink; (5) increased product turnover (Henrickson, 1975; Williams, 1978; Smith, 1980; Kastner, 1982). Also, Solomon and Schmidt (1980) have shown that the ease of salt-soluble protein extraction from prerigor muscle may alter the processing procedure allowing shorter mixing times, larger particle size and reduced salt levels while still achieving a satisfactory bind.
The use of hot processed, prerigor muscle in restructured steaks may also have some disadvantages. Most importantly: (1) a decrease in tenderness due to cold shortening or thaw rigor and (2) difficulty in handling and trimming hot muscle (Williams, 1978; Kastner, 1977). However, conditioning sides at near physiological temperatures for a period of 3-6 h postmortem may alleviate tenderness problems associated with hot processed muscle (Henrickson et al., 1974; Falk et al., 1975).

The objectives of this research were:

(1) To examine the differences in performance and carcass characteristics between South Devon bulls and steers.

(2) To identify any differences in the quality of chunked and formed steaks caused by sex difference.

(3) To incorporate hot processing and high temperature conditioning into the processing scheme of chunked and formed beef steak and examine their effects on the biophysical and organoleptic properties of the restructured steaks.

(4) To examine any differences in the biophysical and organoleptic properties of intact loin steaks caused by sex and chill treatments.
REVIEW OF LITERATURE

Effects of Sex on Growth, Carcass and Palatability Traits

The world supply of food protein is becoming inadequate at a startling rate. Production using present methods, cannot meet the demands caused by increasing populations. In addition, American consumers are becoming more concerned with diet/health issues causing them to insist on a lean, nutrient dense, cost effective product. Because of these demands, the young bull is an attractive alternative to present production systems to help optimize protein production.

Growth Characteristics

Review articles by Hedrick (1968), Field (1971), and Seideman et al. (1982a) all indicate that bulls grow faster and more efficiently than do steers. Warwick et al. (1970) studied the effects of castration on the performance of monozygotic bovine twins and found that bulls had a 23% higher rate of gain and a 16% increase in gain efficiency. Several articles have shown intact males to exhibit at least a 15% increase in daily gain (Cahill, 1964; Field, 1971; Jacobs et al., 1975a, b; Araj et al., 1977) and others have shown at least a 10% advantage (Riggs et al., 1967; Turton, 1969; Ray et al., 1976).

Bidart et al. (1970) found large differences in feed efficiency when feed consumed was expressed in gain of edible product. Steers consumed 12.8 Mcal digestible energy per kg of edible product while bulls consumed 6.0 Mcal. Gregory and
Ford (1983) found that castrated males required 40.4% more metabolizable energy and dry matter/kg of gain than non-implanted intact males.

Arthaud et al. (1977) showed that intact males slaughtered at four different ages (12, 15, 18 and 24 mo) gained faster and were more efficient than their castrated counterparts. Hedrick (1968) summarized that the difference in gain, due to sex, was consistent regardless of age, type or weight for a given group.

Price and Yeates (1969) reported that prior to puberty, intact males had a slight advantage (0 to 5%) in growth rate; however, with the increased androgen production at puberty, there is a likelihood for higher future gains. The increased growth rate and feed efficiency advantage possessed by bulls has been greater on high concentrate than on low concentrate diets (Harte, 1969; Price and Yeates, 1969). Bidart et al. (1970) showed that intact males produced 20% more protein by weight per day per unit of digestible energy consumed than steers. This increase in protein was associated with a positive nitrogen balance which has been ascribed to the protein anabolic effects of testicular hormones (Galbraith et al., 1978).

Carcass Characteristics

Ntunde et al. (1977) reported that with Holstein-Friesian cattle fed to 7.0 mm fat thickness, bulls required more days on feed to reach a fat thickness endpoint but
yielded significantly heavier carcasses that contained less trimmable fat and a higher lean to fat ratio than steers. Other researchers (Nichols et al., 1964; Tanner et al., 1970; Jacobs et al., 1977a; Landon et al., 1978, Crouse et al., 1983; Johnson et al., 1983 and Klastrup et al., 1984) have also reported that bulls have less subcutaneous fat, more longissimus muscle area and less kidney fat than steers. Because intact males had less subcutaneous fat, Field (1971) reported that bulls should have lower dressing percentages. However, Hedrick (1968), Field (1971) and Arají et al. (1977) have found no measurable differences in dressing percent between bulls and steers. In fact, Smith (1982) stated that heavier muscled bulls can dress as high as steers with more external fat since dressing percentage is higher as animals increase in either fat or muscle.

Arthaud et al. (1969) compared the carcass traits of Angus bulls and steers. Bulls produced 13.2 kg more total retail product than steers of equal carcass weight while consuming 141.0 kg less total digestible nutrients. There were no differences in rib and loin weight, but bull rounds and chucks were heavier. Warwick et al. (1970) reported that bulls produced a 12% higher yield of lean from the 9-10-11 rib cut. Bidart et al. (1970) found intact males produced 38% more edible product per unit of digestible energy consumed than castrates. This lean production difference was the result of both reduced digestible energy required per
unit of carcass weight gain and increased percentage of edible product in carcasses of intact males.

Kay and Houseman (1974) reported that bull carcasses contain approximately 8% more muscle and 38% less fat than steer carcasses. Using the Murphy et al. (1960) estimating equation, Field (1971) stated that bulls had an average yield advantage over steers of 2.6% in estimated boneless chuck, rib, loin and round. Champagne et al. (1969) found a difference of 4.8% in actual carcass cutout; whereas, Gortsema et al. (1974) and Jacobs et al. (1977a) found differences of over 9% between bulls and steers using actual cutout data. Cross and Allen (1982) reported that it was difficult to determine if the need for using different prediction equations for estimating composition of bulls was due to differences in sex or to the lack of variation in outside fat in the bull carcasses. Differences in percentage bone are small, but bull carcasses have much higher muscle to bone ratios than steer carcasses (Berg and Butterfield, 1968).

Riggs et al. (1967) stated that bulls produced boneless beef at 11% less cost per unit of weight than steers. Jacobs et al. (1977a) reported that on a boneless basis, bull carcasses contained 58% less crude fat and 23% more crude protein than steer carcasses. In addition, bulls had 17% less cutting trim waste and yielded 5.5% more boxed beef than steers. Bulls were worth approximately 15% more than steers
to the retailer because of higher in-store retail yields. Ray et al. (1976) and Landon et al. (1978) also reported that total retail cuts were greater for bulls than for steers.

Studies conducted by (Field 1971; Ray et al., 1976; Araj i et al., 1977; Crouse et al., 1983; Gregory and Ford, 1983; and Johnson et al., 1983) have shown that intact males have less intramuscular fat and lower USDA quality grades than castrates. Jacobs et al. (1975) found in a three year project that bulls had consistently lower quality grades than steers. The authors realized that this difference may be partially due to a shorter time on the finishing diet. Further studies indicated that a longer time on the high energy diet improved the quality grades for bulls, but they were still below the quality grades for steers.

Arthaud et al. (1977) studied the characteristics of bulls and steers fed at different energy levels and killed at four different ages (12, 15, 18 and 24 mo). Their results show that except for the 12-mo age group, quality grades and marbling scores were higher in steers than bulls for each energy level. Sink et al. (1983) slaughtered bulls and steers at 8, 12, 16 and 20 mo of age. Bullocks contained more marbling than steers at 8 mo of age, but the opposite was true for the other age groups. Marbling in the bullock longissimus muscle did not change significantly from 8 to 20 mo; whereas, the steers increased in marbling creating a large difference in marbling levels at 12, 16 and 20 mo of
age. Klastrup et al. (1984) found differences in quality grade between bulls and steers to be insignificant.

Bull carcasses are more mature physiologically on the basis of bone ossification and lean color than carcasses from steers of the same chronological age (Glimp et al., 1971). Reagan et al. (1971) stated carcasses from steers were more youthful than carcasses from bulls of comparable chronological age. However, bone ossification was the primary factor affecting maturity evaluation in steer carcasses, while lean color was the major factor affecting variation in maturity scores for bull carcasses. Sex x chronological age interactions were observed by Arthaud et al. (1977) for secondary sex characteristics and physiological maturity. At 12 mo of age, differences between bulls and steers in cartilage development were insignificant, but at older ages, bull carcasses consistently exhibited more advanced maturity. Crouse et al. (1983) reported that bull beef possessed more advanced lean maturity ratings than steers. However, results from Klastrup et al. (1984) indicated no difference in lean maturity between bulls and steers.

Numerous other scientists have reported that meat from bulls is darker in color and coarser in texture than meat from steers (Field, 1971; Jeremiah, 1978; Price and Tennesen, 1981; Riley et al., 1982). Under stress free pre-slaughter conditions, no differences in lean color between bulls and steers are usually reported (Rhodes, 1969). As a
result of his research, Field (1971) suggested that because of their temperament, bulls may be more easily stressed than steers, and therefore are possible candidates for dark-cutt-
ters. Kousgaard (1975) reported over 18% of young bulls studied had a 24 h pH values greater than 6.0, resulting in a significantly darker lean color than steers. Price and Tenn-
esson (1981) found that in marketing bulls, load size effects were not significant but mixing and regrouping strange bulls together significantly increased the incidence of dark-cutting muscle (2 vs 73%).

Sorensen (1978), as quoted from Cross and Allen (1982), investigated the use of a highly digestible feed for young bulls prior to slaughter to make it possible to raise the muscle glycogen content prior to death. The results indicated that the high energy diet could increase the glyco-
gen content, allow a lower ultimate postmortem muscle pH and a lower incidence of dark-cutting.

Palatability Characteristics

Pearson (1966) reported that tenderness is the single most important attribute contributing to consumer accepta-
bility of beef. Research by Glimp et al. (1971), Albaugh et al. (1975), Arthaud et al. (1977), Ntunde et al. (1977), and Gregory et al. (1983) has shown that bull meat is less tender than steer meat, but bull meat had acceptable tenderness ratings. In all studies reviewed by Field (1971), meat obtained from bulls was less tender in comparison to steers.
Klosterman et al. (1954) reported only slight differences in tenderness between bulls and steers slaughtered at a relatively young age. Brown et al. (1962) and Lewis et al. (1965) observed minimal tenderness differences between bulls and steers slaughtered at 13 mo of age. Field et al. (1966) slaughtered steers and bulls at four different age periods (300 to 399; 400 to 499; 500 to 599 and 600 to 699 d). Steers were more tender than bulls at all ages. Bulls became less tender as age increased, and the 300 to 399 d old bulls were significantly more tender than the older groups. Hedrick et al. (1969) reported that Warner-Bratzler shear force values and sensory panel scores indicated that steaks from bulls less than 16 mo of age were comparable in tenderness to steaks from steers and heifers of similar age, whereas, steaks from more mature bulls were less tender. Hunsley et al. (1971) concluded that chronological age may have a more adverse effect on tenderness in bull beef than in steer beef.

In contrast, Reagan et al. (1971) stated that steaks from bulls 385 d of age were less tender than steaks from steers of the same age; however, this difference was not apparent between steaks from bulls and steers that were 484 d of age. It was apparent in this study that steaks from bull carcasses were considerably more variable in tenderness than were those from steer carcasses. Ray et al. (1971) found
that on a large scale consumer test, retail cuts from the bull carcasses were more acceptable than those from steer carcasses when evaluated for tenderness.

Results by Field et al. (1966) have shown that the age related changes in tenderness are significantly more pronounced in bulls than in steers or heifers, particularly in muscles high in collagen. These findings suggest that age related changes in the cross-linking of collagen might be related to the sex of the animals (Cross et al., 1982). Boccard et al. (1979) reported that collagen content of muscle was higher in bulls than in steers, regardless of age, and that collagen solubility decreased markedly between 12 and 16 mo in bulls. Boccard and associates speculated that the increase in collagen in bulls between 8 and 12 mo of age is concomitant with sexual development and may be controlled by some endocrine function in the animal. Crouse et al. (1982) found that bulls were different than steers in synthesis of intramuscular collagen at or near 12 mo of age. The increased synthesis of collagen appears to be influenced by testosterone or some other factor associated with puberty. Further support is given by Cross et al. (1983) as their results suggest that the variation in tenderness associated with sex condition was related to the connective tissue component of meat rather than the myofibrillar component.

Hedrick et al. (1969) reported that flavor and juiciness scores of cooked steaks were not significantly affected
by sex condition. In a comprehensive review, Field (1971) found very little differences reported in the flavor of meat obtained from bulls and steers. In addition, Glimp et al. (1971), Laflamme and Burgess (1973) and Ntunde et al. (1977) also found little difference in overall acceptability. Jacobs et al. (1977b) reported that a trained taste panel could not detect significant differences in palatability between bull and steer top round steaks. However, Reagan et al. (1971) reported that steaks from steer carcasses were assigned significantly higher flavor scores than steaks from bulls. Forrest (1975) reported that rib roasts from bulls (less than 15 mo) were less tender, less juicy, less flavorful and received lower overall palatability scores than roasts from steers. In contrast, on their large scale consumer test, Ray et al. (1971) reported that retail cuts from the bull carcasses were more acceptable than cuts from steer carcasses when evaluated for taste and overall acceptability. Sink et al. (1983) reported that bulls had higher expressible juice values than steers.

Hedrick et al. (1969) and Arthaud et al. (1977) reported that chronological age did not seem to influence the flavor and juiciness scores of steaks from bulls. Field et al. (1966) reported that flavor and juiciness scores of steaks were not affected by age of bulls when marbling was held constant, but roasts from older bulls were scored lower.
Reagan et al. (1971) noted that steaks derived from bulls may acquire undesirable flavor traits between the ages of 385 and 484 days of age.

Although consumers can detect differences in palatability between bull and steer beef, this does not imply that beef from young bulls is "unacceptable." It is quite possible that either present and future consumers have or will have a lower threshold of acceptability/unacceptability than did those of the past or that leanness is becoming relatively more important than palatability (above some threshold level). If so, bull beef should have an excellent future (Cross, 1982).

Restructured Meats

An objective of the meat industry is to provide the consumer with a highly palatable product at a reasonable cost. The utilization of less valuable carcasses (cows and bulls) and carcass components (plates, flanks, etc.) is of prime interest in periods of economic pressure in the livestock industry. Economic pressure to minimize cost and maximize product utilization provides the incentive to develop new products using less valuable carcasses and carcass components. The overall concept of restructured meat products is to utilize less expensive beef cuts to manufacture a product that provides satisfactory eating qualities at a reasonable unit cost (Seideman and Durland, 1982).
Reduction of particle size in the raw meat material is usually the first step in the restructuring process. While particle size reduction is a basic step in the process, it can be accomplished by a variety of methods. Grinding refers to the use of plate grinders with varying plate sizes and configurations. Chunking may be accomplished manually, with plate grinders or mechanical dicers. Sectioning involves the separation of entire muscles by seaming. Flaking requires the use of an Urschel Comitrol (Urschel Laboratories, Valparaiso, Indiana) or similar piece of equipment. In flaking, the meat is forced against stationary precision-honed shearing heads, resulting in uniform-sized flakes of meat. Slicing involves the formation of thin "wafer-like" slices of meat varying in thickness from 2.5 mm to 7.5 mm (Huffman, 1982).

The advantages claimed for flaking meat when compared to grinding include improved texture, retention of natural juices (less drip loss), better cohesive properties, reduced cooking losses, improved sensory characteristics (acceptability of color, flavor, juiciness, tenderness) and reduction in connective tissue perception (Fenters and Ziemba, 1971; Ferren, 1972; Anonymous, 1976). Randall and Larmond (1977) observed no difference in bacterial counts or cooking loss between flake-cut and ground hamburger patties; however, flaked patties had a lower total drip loss. Although the
same comminution size was used for both grinding and flaking (6.35 mm), a trained sensory panel revealed that ground meat patties had a finer grind, were more tender, less rubbery, juicier and greasier than flake-cut meat.

Chesney et al. (1978) found no differences in water holding capacity (WHC), cooking loss or shear values between flaked and ground pork. However, an untrained taste panel evaluation showed the flaked product to be more cohesive and acceptable overall than ground pork. Costello et al. (1981) compared sliced, flaked and ground methods of comminution for restructured beef steaks. Lee-Kramer shear values indicated that both flaked and ground steaks were more tender than intact or sliced round steaks. In contrast to the work of Chesney et al. (1978), Costello et al. (1981) found no differences in overall palatability, regardless of the method of comminution. It was noted however, that restructured steaks manufactured with flaked or ground beef were more mushy and crumbly than steaks manufactured with sliced beef. Ockerman and Organisciak (1979), while studying the quality of restructured beef steaks after refrigerated and frozen storage, found that thinly sliced beef chuck muscles with 2% salt and 3% added water could be utilized to make a desirable restructured product. Slicing can allow for increased extraction of proteins and the intermuscular fat is in such a form that it can be evenly dispersed throughout the product in the blending process (Huffman, 1982).
Chunking raw meat materials to form a restructured product works well in the restructuring process (Huffman and Cordray, 1979). In the chunking procedure, large muscles are seamed and manually or mechanically cut into chunks. Most often, chunks are formed by grinding through a kidney plate which gives a more irregular surface to the chunk, resulting in more surface area for the extraction of proteins and, therefore, better reforming ability than manual chunking or use of a dicer (Huffman, 1982). The primary advantage of this process is that the final restructured steak product has visual and palatability attributes more nearly resembling muscle-cut steaks than restructured steaks made with flake-cut particles (Huffman, 1982; Mandigo, 1982). The major disadvantage of the chunking process is that the fat content must be lower than that of flake-cut products because the fat particle size is much greater and, therefore, more readily noticeable in the final product (Huffman, 1982). Also, Huffman and Cordray (1979) and Borren et al. (1979) have reported that the finished chunked beef product has a tendency to develop off colors.

A sectioned and formed meat product is a boneless product in which the muscles are separated so that connective tissue and excess fat can be removed. The muscle is then reformed and shaped (Booren, 1980). Tumbling and massaging are the two most popular methods for the production of sectioned and formed meat products.
Cassidy et al. (1978) explained that tumbling involved the physical process of meat rotating in a drum, falling and making contact with metal walls and paddles. The process involved a transfer of kinetic energy and consequently caused the alteration of muscle tissue. Weiss (1974) stated that the primary aim of tumbling was to produce enough protein exudate consisting mainly of the salt soluble proteins actin and myosin to effectively promote cohesion during heating and to develop desirable textural characteristics.

Massaging is a less severe treatment than tumbling. Slow massaging involved rubbing meat against meat in a large square stainless steel vat (Anon, 1977). Schmidt (1977) stated that massaging was actually a slow mixer designed to act gently and stir large chunks of meat. Siegel et al. (1978a) stated that the massaging process was considered as a mechanism which not only aided the extraction and solubilization of the myofibrillar protein, but also acted as a mechanism for the even distribution of the proteins on muscle surfaces. Mandigo (1982) stated that sectioned and formed products have a more desirable intact muscle-like texture than flaked products.

**Particle Size**

Particle size is an important factor affecting the texture of restructured meat products (LeMaire, 1978). The finer the particle size, the larger the surface area. An increase in surface area promotes the release of muscle fiber
contents which: (1) form a moist surface to surface exudate; (2) can be solubilized in the pressure of salts and (3) can form a bond between similar surfaces (Acton, 1972). Acton (1972) also showed that the finer the particle size, the more salt-soluble proteins were extracted. This situation caused lower cooking losses and greater binding strengths.

Chesney (1973) reported that the percentage of cooking loss decreased with decreasing particle size in a study with pork. Taste panel evaluation indicated that the smaller particle sizes were more cohesive, juicy, more tender and acceptable than the larger size particles. Chesney et al. (1978) compared three grinding sizes and three different flake sizes for restructured pork. Decreases in cooking loss were associated with decreases in particle size; however, no differences in shear force values were observed. Taste panel scores indicated that decreasing the particle size increased product bind, juiciness and tenderness.

Popenhagen and Mandigo (1978) compared three flake sizes and two comminution temperatures for the production of restructured pork. Smaller particles, when processed at \(-5.6\,^{\circ}\text{C}\) resulted in a less cohesive, less tender cooked product. Flake size at \(-5.6\,^{\circ}\text{C}\) did not affect cooking loss or WHC. Larger flake sizes processed at \(2.2\,^{\circ}\text{C}\) were more tender, juicy and had higher overall acceptability, but had lower cooking losses than small flakes at \(2.2\,^{\circ}\text{C}\). Popenhagen and Mandigo (1978) concluded that a more desirable product could
be produced by blending a small flake and a large flake, each cut at a different temperature, in a 50:50 ratio.

Durland et al. (1982) reported that overall appearance ratings generally decreased as particle size increased. Neither moisture loss nor total cooking loss were significantly affected by particle size, but fat loss increased as particle size increased. Particle size had no effect on sensory scores for flavor or juiciness. Increased particle size decreased tenderness and overall palatability. Booren et al. (1979) found that restructured beef steaks that closely resemble intact steaks could be produced from rounds when ground to a 5-7 cm particle size.

**Meat Temperature**

Mandigo (1974) observed that the temperature of the trimmings and meat ingredients used in restructured products is extremely important with respect to the texture and appearance of the finished product. Cold flakes (-5 C) are important in providing the "bite" or texture of the finished products. Farrington (1975) stated that temperature is important as it determines the amount of cohesion in the finished product. The exact temperature needed to ensure the most desirable sensory attributes varies from product to product. Mandigo (1974) stated that flaking meat above 25-26 F (-4 to -3 C) caused smearing of the flakes. At temperatures below 21 F (-6 C), explosions occurred and fluffy flakes are
the result. Urschel Laboratories (1973) recommended that the temperature of the meat for restructured meat processing should be maintained at -4 to 4°C during the processing operation.

Mandigo (1975) and Popenhagen et al. (1973) found that the leanest trimmings should be flaked through the coarser flaking head at the coldest temperatures (-4 to -5°C). These trimmings are important for the mouth feel of the finished product. The other meat component of the blend is the fatter source of trimmings, flaked through the finer head at warmer temperature (0 to 2°C). The finer head will make the fat particles a more acceptable size.

Chesney et al. (1978) evaluated three meat temperatures (32.3, 2.2, or -5.6°C) at the time of flaking or grinding. As temperature decreased, cooking losses and Warner-Bratzler shear force values increased. Sensory panelists indicated that meat processed at 2.2°C was more cohesive than the other temperatures. This temperature produced a product which panelists found more desirable than the low processing temperature. Costello et al. (1981) observed that steaks made from meat flaked at 2.2°C had less visible fat, a finer textural appearance and a higher overall appearance than steaks produced from -2.2°C and -5.0°C flaking temperature. However, products produced at lower temperature (-2.2°C and -5.0°C) were given higher flavor scores and overall palatability ratings by panelists.
Mixing Time

Following comminution, mixing is employed as a means of achieving uniform distribution of lean and fat components and of additives. It also facilitates the extraction of intracellular proteins to the meat surfaces (Breidenstein, 1982). The length of mechanical mixing time is very critical to the release of protein which is required to bind the flakes of meat together (LeMaire, 1978). In addition, blending of flaked meat for restructured meat processing affects interlocking of the flakes and allows interaction of air with the meat. Blending, therefore, improves color and texture through the uniform inclusion of oxygen through the meat mass (Farrington, 1975).

Belohlavy and Mandigo (1974) and Belohlavy (1975) found no significant effect of mixing time on firmness, binding strength, penetrometer reading or shear value of flaked products. They concluded that mixing times of 8 to 10 min were the most desirable as these times offer a good compromise for all quality factors. Similarly, Farrington (1975) stated that for best results, blending time should be kept within 8 to 10 min.

Maesso et al. (1970) looked at various beating or mixing times on the binding quality of poultry loaves. They studied blending times ranging from 0 to 6 min. They found that mixing longer than three min caused undesirable changes in the loaves. In the production of beef rolls, Pepper and
Schmidt (1975) found that increasing mixing time increased cooking yields but had little effect on binding strength.

Booren et al. (1981a) studied the effects of various mixing times (0, 6, 12 and 18 min) on quality of chunked and formed beef steak. Panel evaluations of connective tissue residue showed no difference for the mixing times. Cooking yields increased with the increased mixing times through 18 min. Increased mixing time up to 18 min continued to improve the texture, juiciness, flavor and tenderness values for the chunked and formed steak. Durland et al. (1982) formulated flaked steaks with mixing times of 0, 5, 10 or 15 min. A mixing time of 5 min resulted in higher scores for juiciness and tenderness as compared to steaks made from meat mixed for 15 min. Mixing time had no significant effect on cooking losses or binding strength. The differences in observations (Booren et al., 1981a, b vs Durland et al., 1982) may be the result of different raw materials. Booren et al. (1981a, b) used coarse ground muscle while Durland et al. (1982) used flaked muscle.

Coon (1982) studied different mixing times (0, 6, 12 or 18 min) in formulating sectioned and formed steaks. The results indicated that cooking yields, bind and tenderness of restructured prerigor steaks were enhanced by the longer mix time. Mandigo (1982) stated that protein solubilization that occurred during mixing is also a function of the temperature.
Greater myosin solubilization occurs at colder temperatures approaching the freezing point of the meat system. Mandigo (1982) further reports that restructured processing is recommended at or near 0°C for reasons of protein solubilization, particle flaking, more effective mixing and tenderization when the mechanical tenderizer is used. Mixing beef when its temperature is over 7.2°C allows flakes to become mushy and the final product to have a rubbery texture. If temperatures are too low, mixing time must be increased to allow sufficient binding to occur (Anon, 1976).

Solomon (1979) reported that more crude myosin could be extracted when vacuum was applied to an extraction procedure. This additional myosin could create a more desirable bind between meat pieces. Booren et al. (1981b) studied the effects of vacuum vs non-vacuum mixing on the chunked and formed steaks. Sensory analyses indicated vacuum processed steaks had superior bind while other sensory trials remained unchanged. Subjective color scores indicated less desirable color for vacuum mixing. Using spectrophotometric analysis (%R630 - %R580), vacuum mixing produced less desirable surface color in finished steaks. Wiebe and Schmidt (1982a) stated that vacuum mixing was responsible for an increased binding strength of the restructured steak, but showed no effect on the cook yield. In another study, Wiebe and Schmidt (1982b) stated that vacuum mixing lowered the
cook yield, but had no effect on binding strength of restructured beef.

Chemistry of Meat Binding

"Restructuring of meats" refers to the binding together of meat pieces, to form a cohesive mass. The binding of these meat pieces is achieved by solubilizing protein, bringing the soluble protein to the meat particle surface, putting meat particles in contact with each other, pressing into more desirable shapes and heat setting these proteins during cooking (Smith, 1982). The most important feature of restructured meat products is the ability of the protein matrix formed to effectively bind the meat pieces together. Effective bind is essential if the product is to retain its structural integrity during subsequent handling and slicing (Schmidt, 1982).

Role of Specific Proteins in Binding Meat Protein:

Muscle proteins can be divided into three groups: (1) myofibrillar; (2) sarcoplasmic and (3) stromal proteins. Stromal proteins, which include collagen, elastin and reticulin, are not salt soluble and will remain in muscle tissue extracted with strong salt solutions. The sarcoplasmic proteins consist of myoglobin, hemoglobin and numerous metabolic enzymes and account for 20 to 30% of the total muscle protein. These proteins are the most easily extracted and are classified as the "water soluble" proteins because they can be extracted with very low ionic strength solutions (0.1 to 0.2M).
The myofibrillar proteins make up 60% of the total muscle proteins. The main constituents are myosin (50-55%), actin (15-20%) and tropomysin. Myofibrillar proteins are considered "salt soluble" because they are soluble in 0.6M salt solutions. Sarcoplasmic and myofibrillar proteins are relatively easily solubilized and represent a significant portion of the meat proteins.

The binding properties of numerous sarcoplasmic and myofibrillar proteins have been studied extensively. It was reported by Fukazawa (1961a) that the sarcoplasmic proteins exhibited little influence on the binding quality of meat. Swift et al. (1961) studied the capacity of fat uptake which is of primary importance in emulsion products. It was concluded that the myofibrillar proteins were responsible for fat binding and subsequent particle binding in emulsion products. The sarcoplasmic proteins were found to exhibit no measurable binding properties unless salt was added. The myofibrillar protein fraction was found to have superior binding properties.

Acton and McCaskill (1972) studied the importance of sarcoplasmic proteins in the binding of meat pieces in poultry loaves. They removed 35% of the sarcoplasmic proteins, mainly from the meat surface, by washing the pieces with deionized water. The binding ability of the washed pieces was measured, either with or without 2% added salt. They found that the binding ability of the washed meat cubes, both in
the presence and absence of 2% salt, did not differ significantly from that of the unwashed control meat pieces. In spite of the increased percentage of myofibrillar proteins at the meat surface, caused by the removal of sarcoplasmic proteins, there was no increase in binding ability. Siegel and Schmidt (1979a) obtained similar results. They found that even with complete removal of the sarcoplasmic proteins, there was no significant increase in binding ability in the presence of 6% salt and 2% sodium tripolyphosphate.

Macfarlane et al. (1977) reported that sarcoplasmic proteins was found to be a poor binder of meat pieces, but its presence helped to enhance the binding abilities of the myofibrillar proteins at low salt levels. Ford et al. (1978) stated that both subjective and objective measures indicated sarcoplasmic proteins were poor binders when added to meat pieces being restructured to steakettes. The general conclusion that can be drawn from previously cited research is that when the ionic strength of the binding matrix is low (below 0.4M), the sarcoplasmic proteins make a significant contribution to the binding ability of meat pieces. However, when the ionic strength is increased beyond 0.4M, sarcoplasmic proteins have little beneficial effect on binding ability (Schmidt 1982).
The myofibrillar proteins are primarily myosin, tropomysin and actin. Fukazawa et al. (1961b) provided electron microscopy evidence indicating that actin and tropomyosin do not influence the binding quality of sausage in a model system. Myosin in fibrils was found to have the greatest effect on binding. Fukazawa et al. (1961a) demonstrated that myosin contained the binding qualities when extracted from the fibril. Free myosin or myosin in the form of actomyosin was considered to play a major role in sausage binding. Acton (1972b) found that an increase in salt soluble protein extractability and the increase of binding strength were significantly correlated. This research would support the hypothesis that salt soluble myofibrillar proteins acted as the binding agents. It was generally concluded by Fukazawa et al. (1961a), Samejima et al. (1969), and Nakajama and Sato (1971a, b) that myosin and actomyosin were the proteins most important in binding. In addition they found in most cases, that actomyosin was a more effective binding agent than myosin.

Macfarlane et al. (1977) found myosin to be superior to actomyosin at low salt concentrations (below 1.0M). At higher concentrations binding of actomyosin was similar to myosin. The best binding ability was found in a mixture of myosin and sarcoplasmic proteins with no salt present. Galluzzo and Regenstein (1978a) found that myosin is the most rapidly solubilized protein and forms thick, creamy
emulsions in model systems. Alone, the actomyosin complex performs like myosin, and when dissociated, actin and myosin act independently. Actin appears to contribute very little to good emulsion formation. When compared to actomyosin, myosin was reported to be a superior emulsifier (Galluzzo and Regenstein, 1978b). Ford et al. (1978) stated that myosin had the highest binding ability in beef steakettes when analyzed both subjectively and objectively. Siegel et al. (1978a) found actin and myosin extraction to be a prerequisite for good binding quality. Siegel and Schmidt (1979a) reported the binding ability of myosin in a model system of meat pieces was superior to any other combination of muscle proteins. When the mole ratios of myosin to actin were compared under similar conditions, a higher ratio was positively correlated with better binding. Turner et al. (1979) demonstrated that myosin binds better than actomyosin and that the rate of extraction does not change myosin's binding ability.

A possible explanation may be found in the research of Yasui et al. (1980) for the discrepancies in results between researchers on the comparison of which in a better binder, myosin or actomyosin. Yasui et al. (1980) showed that the addition of myosin to actomyosin produced a gel that was much stronger than either myosin or actomyosin when used separately. Thus, the results reported by Macfarlane et al. (1977) may be explained by the interaction of the added
myosin with the actomyosin present on the surface of the meat to form a strong binding matrix and the inability of acto-myosin to do similarly.

Salt as a Meat Additive: The most important functional property of sodium chloride is its ability to increase the extractability of salt soluble proteins. This in turn increases binding of proteins, fat and water (Kramlich, 1973). The mechanisms by which salts increase the binding ability of a protein matrix are: (1) By increasing the amount of protein extracted, (2) by altering the ionic and pH environment so that the resultant heat-set protein matrix forms a coherent 3-dimensional structure (Schmidt, 1982).

Schnell et al. (1970) demonstrated the mechanism of salt on myofibrillar protein extraction. In general there was a linear increase for binding as salt concentration increased. Cookout decreased about 60% with a 2% sodium chloride addition. This cookout fraction was analyzed for nucleic acid content. Nucleic acids were found to increase by a factor of 20 with salt addition. The amount of total nucleic acids was concluded to be a result of the osmotic effect of salt causing cell disruption and a release of intercellular materials which would include myofibrillar proteins.

Yasui et al. (1980) reported that mixtures of actin and myosin exhibited maximum gel strength at pH 6.0 and an ionic strength of 0.7M. Siegel et al. (1979a) proposed an
explanation why salts increase gel strength. Using scanning election microscopy, they demonstrated that when myosin and actomyosin were heated in high ionic-strength solutions, the proteins formed a coherent three-dimensional network of fibers. In the absence of added salts, the same proteins formed a spongy structure with little strength. They concluded that the characteristic three-dimensional structure produced by the addition of salts was necessary for the meat proteins to produce a satisfactory bind. Yasui et al. (1980), also using scanning election microscopy, found that the same type of structure occurred for both myosin and actomyosin at pH 6.0 and ionic strength of 0.6.

Hamm (1960) explained the mechanism of increased water holding capacity upon sodium chloride addition. The chloride ion was bound to the proteins positive charged group involving most of the exposed groups. Sodium was only weakly bound to the negative charges. The result was that the isoelectric point was moved towards a lower pH. This displacement caused an increased space between the filaments at or above pH 5 and increased the protein molecules ability to bind water.

Sulzbacher et al. (1960) reported the addition of salt increased the ionic strength of the meat mixture and caused a structural rearrangement of the meat proteins. This action made salt soluble proteins more available for protein binding. Maesso et al. (1970) demonstrated with poultry
loaves that even without mechanical treatment, the addition of salt increased the strength of the bind over the control. Acton and McCaskill (1972) reported that by decreasing partical size and increasing amounts of sodium chloride they caused the solubilization of larger quantities of muscle proteins which resulted in a stronger bind between meat particles.

Pepper and Schmidt (1975) stated that salt addition increased the binding strength of meat pieces in the form of a meat roll. Reynolds et al. (1978) reported similar results for the binding strength of ham rolls using 0, 0.5, 1.0 and 2.0% salt. When studying the effect of salt on a flaked, cured pork product, Neer and Mandigo (1977) reported a linear increase in binding strength as salt addition increased. Siegel et al. (1978b) reported that breaking force of sectioned and formed ham increased due to salt addition. Dalton (1979) observed increased tensile strength of the muscle bond when salt was added to sectioned and formed pork chops at a 0.5% level. Huffman and Cordray (1979) reported similar increases in bind strength by adding salt to formulations of restructured pork chops.

Phosphate Addition: Solomon (1979) proposed four theories explaining the role of phosphate on meat: (1) the interaction of phosphate ions with protein ions, (2) cation chelating abilities, (3) a change in pH and (4) binding interactions with myosin. Fukazawa et al. (1961c) found that
phosphate added to an extracting solution increased the amount of extractable protein. This effect depended upon the type of phosphate used, with hexametaphosphate lowest, pyrophosphate highest and tripolyphosphate intermediate. Froning (1965 and 1966) reported that polyphosphates increased the binding properties of poultry loaf products. Maesso et al. (1970) stated that phosphates along with beating increased the binding strength of meat loaves, when used in combination with sodium chloride. Pepper and Schmidt (1975) and Moore et al. (1976) also reported increased binding strength when phosphates were added with salt in beef rolls.

Ockerman et al. (1978) reported that the addition of salt and phosphates along with a short tumbling time increased the cohesion between meat chunks in cured, canned pork. In sectioned and formed ham, Siegel et al. (1978b) reported that phosphate increased the amount of exudate on the meat surface which increased bind. Krause et al. (1978) stated that phosphate addition increased salt migration and binding strength in sectioned and formed hams. Schmidt and Siegel (1978) concluded that phosphate increased the extraction of actin, myosin and tropomyosin. The site of this added extraction was primarily on the surface of the meat chunks prior to any mechanical treatment. Phosphate alone, yielded a superior product bind than just massaging alone. However, both phosphates and massaging in combination yielded an overall superior product. Siegel et al. (1978a) found
amount of extractable protein. This effect depended upon the type of phosphate used, with hexametaphosphate lowest, pyrophosphate highest and tripolyphosphate intermediate. Froning (1965 and 1966) reported that polyphosphates increased the binding properties of poultry loaf products. Maesso et al. (1970) stated that phosphates along with beating increased the binding strength of meat loaves, when used in combination with sodium chloride. Pepper and Schmidt (1975) and Moore et al. (1976) also reported increased binding strength when phosphates were added with salt in beef rolls.

Ockerman et al. (1978) reported that the addition of salt and phosphates along with a short tumbling time increased the cohesion between meat chunks in cured, canned pork. In sectioned and formed ham, Siegel et al. (1978b) reported that phosphate increased the amount of exudate on the meat surface which increased bind. Krause et al. (1978) stated that phosphate addition increased salt migration and binding strength in sectioned and formed hams. Schmidt and Siegel (1978) concluded that phosphate increased the extraction of actin, myosin and tropomyosin. The site of this added extraction was primarily on the surface of the meat chunks prior to any mechanical treatment. Phosphate alone, yielded a superior product bind than just massaging alone. However, both phosphates and massaging in combination yielded an overall superior product. Siegel et al. (1978a) found
phosphates to have the greatest positive effect on relative percentages of actin, myosin and tropomyosin in meat surface exudate. This observation is confirmed by data provided by Turner et al. (1979) for myosin.

Phosphates act to increase water holding capacity in several ways (Hamm, 1970). First they cause the partial elimination by precipitation, sequestering or ion exchange of $^{2+}$ Ca, $^{2+}$ Mg, $^{2+}$ Zn and alkaline earth metals from the meat and increase the spaces between meat proteins. They also cause the partial dissociation of actomyosin and change the structural arrangement of the proteins leaving more sites open for protein-protein interactions. Finally, phosphates increase the ionic strength of the meat and cause the pH to rise thus increasing the water holding capacity.

**Non-Meat Proteins:** Sodium (from sodium chloride) has been linked with aggravated hypertension and has created an incentive for reducing sodium levels in processed meats. An estimated 20% of the U.S. population have some degree of hypertension and 10-30% of these people may benefit from lower sodium intake. (Andres, 1982). With this in mind, research has been going on for a period of years to examine alternative meat binders as a partial replacement for sodium chloride. For a non-meat protein to be effective, it must be readily soluble and have binding properties similar to myosin.
Froning (1966) reported that dried milk solids and gelatin were found to increase binding of ground chicken. They were not as effective as naturally occurring proteins when extracted with appropriate salt and phosphate. Moore et al. (1976) compared the binding effects of delactosed whey, soy isolate and textured soy in cured beef rolls. The delactosed whey was superior to other non-meat proteins compared, but it had only two-thirds the binding ability of myofibrillar proteins extracted with 1% salt and 0.25% phosphate. Siegel et al. (1979a) stated that injecting soy isolates into a ham product and massaging caused yield and sliceability of the intact muscle to increase. The extracted myofibrillar proteins in this system seemed to enhance the intrinsic function of the soy isolates. Also, the soy isolate enhances the extractability of the myofibrillar proteins by binding water.

Siegel et al. (1979b) compared the binding abilities of selected non-meat proteins. All non-meat proteins were found to be inferior to the binding values of myosin and actomyosin. When ranked from highest to lowest in binding ability, they found the order to be, wheat gluten, egg white, corn gluten, calcium reduced dried skim milk, bovine blood plasma, isolated soy protein and sodium caseinate. The ability of non-meat protein to bind to meat pieces was related to its ability to interact with myosin during heating.
Cardello et al. (1982) stated that 1% added soy isolate to flaked and formed steaks produced a texture that was no different from the flaked and formed steaks containing NaCl and TPP. They suggest that soy isolate assisted in the binding of meat flakes. Terrell et al. (1982) evaluated binding properties of vital wheat gluten, isolated soy protein, plasma protein, egg albumen and sodium caseinate in muscle-juncture formation. The control (no-protein added) and sodium caseinate samples did not form adequate junctures between meat pieces to measure. Junctures formed with animal proteins (plasma protein and egg albumen) were superior to junctures formed with plant proteins (vital wheat gluten and isolated soy protein). Terrell et al. (1982) suggested that the decreased binding was due to metal ions and/or insoluble materials in the plant proteins which may interfere with hydration mechanisms of these protein products, as well as hydration of myofibrillar proteins at the meat surfaces.

Binding as a Heat Mediated Reaction: Swift (1965) theorized that the binding qualities of myosin and actomyosin may be due to the alpha-helical content of myosin. Hamm (1966) stated that the helical portions of the protein unravel during heating to a random form. These random forms produce cross-links both of ionic and hydrogen bonds. This cross-link formation is thought to be the basis of heat initiated binding (Vadehra and Baker, 1970). Rust and Olson (1973) reported that proteins had two main functions:
1. During heat processing these proteins of which myosin was the major constituent, will coagulate and will act as a bonding agent, holding the meat surfaces together.

2. The same protein which acts as a bonding agents will act as a sealer when thermally processed thus facilitating the retention of the moisture contained in the meat tissue.

Acton (1972a, b) found that binding strength among meat particles was temperature dependent. The temperature was critical because it influenced the amount of denaturation or coagulation of the salt soluble and water soluble proteins (Hamm, 1966). Acton (1972b) reported that binding began at approximately 40°C and reached a maximum of 82°C. Yasui et al. (1979) used pure myosin gels and evaluated them with scanning electron microscopy, nuclear magnetic resonance and a gel shear modulus. They concluded that the "sol" to "gel" state occurs in the temperature range of 40°C to 80°C. Siegel and Schmidt (1979a) also demonstrated that binding ability of myosin between meat pieces increased over this same 40°C to 80°C temperature range.

Effects of Additives on Palatability

Cross and Stanfield (1976) concluded that salt is beneficial to consumer preference of flaked and formed steaks. Schwartz and Mandigo (1975 and 1976) found more desirable aromas and increased flavor ratings due to the addition of salt to flaked and formed pork. Juiciness, raw color, cooking loss, TBA values, aroma and flavor were improved by the addition of salt and sodium tripolyphosphate (STP). Dalton (1979) observed that salt treatments were
rated more tender and flavorful. Salt was found to play an important role in the development of desirable chemical, physical and organoleptic properties of sectioned and formed chops. Huffman and Cordray (1979) confirmed these observations when restructuring with thin slices and lean cubes. Huffman et al. (1981a) found increased juiciness, increased flavor and more desirable color due to the addition of salt to flaked and formed hamburger patties. In flaked and formed pork products, Schwartz (1975) reported that phosphate incorporation yielded better texture and an overall superior product. Neer and Mandigo (1977) confirmed these observations for cured restructured pork and also noted a linear increase in flavor strength with phosphate addition. Mandigo (1976) recommended 0.75% salt and 0.125% STP for producing flaked and formed pork. Mandigo and Booren (1981) reported that the addition of salt increased juiciness, flavor and texture ratings.

Cross and Stanfield (1976) reported that consumer panelists showed the greatest preference for the restructured steaks with 30% fat (rather than 20%) and added salt. The addition of salt to the formulation enhanced the consumer response to all palatability traits regardless of fat level. Levick (1978) evaluated the effects of four fat levels (10, 20, 30 and 40%) on restructured pork and beef products. Panelists preferred beef steak containing 10 and 20% fat rather than the 30 and 40 percent fat treatments. In
restructured pork chops, taste panel results revealed higher
tenderness and juiciness ratings with increased fat content
for pork. Levick (1978) concluded that the optimum fat level
for flaked and formed beef and pork was 20%.

Cookery Methods

Decareau (1971) reported that no single heating
device gives perfectly satisfactory results. Campbell (1976)
found that cooking restructured pork patties with a convec-
tion oven produced significantly lower aroma scores, cooking
losses and area changes than with an electric grill. No
differences were observed between the two cooking methods for
color, visual texture, flavor or eating texture. Campbell et
al. (1977) reported that when comparing oven cooking tempera-
tures of 149, 177, 204, 232 and 260°C, a cooking tempera-
ture of 177°C was found to have the highest yield of cooked
product as determined by cooking loss. A steak sliced 190 mm
thick and then cooked in a 177°C oven was recommended to
yield the most satisfactory results. Quenzer et al. (1983)
investigated various cooking/preparation methods including
broasting, oven roasting, grilling and deep-fat frying with
and without breading. Panelists generally preferred grilled
(breaded or unbreaded) steaks to oven and deep-fat fried
steaks.

Restructured Meat Color

The consumer considers the bright red color of
oxymyoglobin in fresh meat desirable, while the brown color
of metmyoglobin is considered less desirable (Frank and Solberg, 1971). The change of oxymyoglobin to metmyoglobin results from the slow oxidation of the heme iron to its ferric state. As this change occurs the meat becomes less acceptable to consumers (Strange et al., 1974). van den Oord and Wesdorp (1971) stated that at approximately 50% conversion to metmyoglobin the meat is unacceptable to most consumers and therefore unsuitable for retail sale. Color (or the perception of color) is an important characteristic of restructured meat. Any deviation from colors perceived in fresh intact muscle will cause a decline in overall acceptability of a new product such as a sectioned and formed beef steak (Booren and Mandigo, 1981).

Color of a food has been correlated with sensory, nutritional, visual and non-visual defects (Kramer, 1976). Therefore, accurate color measurement is important in the evaluating of meat products. Color measurements using the human eye are influenced by lighting, personal preference and deficiencies in the eye itself. However, the human eye will relate the total impression, while objective measures tend to evaluate single pigments that are found in a small area.

A common method for measuring consumer acceptance of color is evaluation by a panel of trained observers. This method has several disadvantages for evaluation of meat color. Panel measurements are time consuming, prone to subjective errors and limited in the number of evaluations which
can be made at one time (Strange et al., 1974). Therefore, an accurate and precise technique is required for determining the relative quantities of oxymyoglobin, metmyoglobin and total pigment concentration at the surface of the meat sample. Reflectance measurement is a popular method because it measures the color on the surface of the meat as observed by the consumer and it is nondestructive. The method described by van den Oord and Wesdorp (1971) uses %R630-%R580. Reflectance at 630 nm is high for oxymyoglobin and low for metmyoglobin. The reverse is true at 580 nm. The difference of these two values indicates a brighter color.

van den Oord and Wesdorp (1971) stated that for reflectance measurements, meat samples should fulfill certain requirements. First, meat slices must be of sufficient thickness to prevent light transmission. Secondly the muscle fiber orientation should be the same for all samples measured. Samples with the fibers parallel to the surface give a higher reflectance than samples sliced perpendicularly to the fibers. In the case of restructured meats, this second requirement may indicate a problem in using reflectance spectrophotometry as an objective measure of color.

Huffman and Cordray (1979) and Booren et al. (1979) suggested that color deterioration occurs during processing. Booren et al. (1981a) reported that mixing longer than 12 min increased color deterioration (conversion to more metmyoglobin) in sectioned and formed steaks. Booren et al.
(1981b) stated that vacuum mixing produced a less desirable surface color in finished steaks, but differences were small and a highly desirable color was still present. Schwartz and Mandigo (1976) observed a less desirable color with increased salt levels, but the use of sodium tripolyphosphate (STP) improved raw color scores. Huffman and Cordray (1979) reported similar results using salt and STP and also stated that the color of restructured pork chops is less desirable than intact loin chops. Huffman and Cordray (1981b) reported that increased salt levels were detrimental to raw color scores of restructured pork chops when evaluated at 0 and 30 d.

Restructured Meat Storage

Objective tests for following organoleptic deteriorations in food products are highly desirable. One such test is the reaction of 2-thiobarbituric acid (TBA) with the oxidation products of unsaturated fatty acids to give a red pigment. The main oxidation product involved is malonaldehyde (Tarladgis et al., 1960). TBA values were first used by Turner et al. (1954) to quantitate rancidity in milk products. Younathan and Watts (1959) found the TBA value to be a good indication of rancidity in cooked products. Tarladgis et al. (1960) improved the procedure by eliminating the development of rancidity that occurred during the isolation procedure. They accomplished this by requiring a homogenized
sample and a rapid distillation process. Watts, (1961) hypothesized that TBA is correlated with rancid odors and flavors; however, it is unclear how high TBA values must be before undesirable odors or rancid flavors are detected.

Schwartz and Mandigo (1976) found that added salt and STP increased TBA values on fresh restructured pork. Neer and Mandigo (1977) found that salt enhanced rancidity but STP retarded its development in restructured cured pork. This may indicate that only in a cooked meat system will the phosphate function to protect flavor. Campbell (1976) found that TBA values increased with time for cooked restructured pork patties. Huffman et al. (1981b) reported that TBA values of restructured pork (prepared from chunks, thin sliced and ground pork) increased linearly with increasing salt levels (0.0, 0.5, 1.0 and 1.5%). Booren et al. (1981a) also reported increased oxidation in restructured products with increased salt levels. Ockerman and Organisciak (1979) reported rapid deterioration of both raw and cooked sensory quality with the addition of salt in restructured beef steaks and suggest antioxidants or phosphates be added for a more acceptable shelf life.

Hot Processing

Hot processing is used here as a descriptive title; however, other terms are used to describe hot processing. They include hot boning, ante-rigor excision, prerigor excision, accelerated processing, high temperature processing,
pre-chill processing, hot cutting and processing, processing prior to rigor mortis and rapid processing (Kastner, 1977). Hot processing is the removal of muscle or muscle systems from the carcass prior to chilling. This processing system offers both advantages and disadvantages (as discussed in the introduction) to the meat processor. Kastner (1977) states that to a large extent, successful hot processing hinges on minimizing or eliminating the adverse effects.

Advantages

Henrickson (1975) and Noble and Henrickson (1977) reported that the space required to chill the edible portion of a 600 pound choice beef carcass requires 80% less space than conventionally chilled whole carcasses. McLeod et al. (1973) estimated that if hot processed lamb primal cuts could be satisfactorily conditioned in cartons, conditioning space requirements could be reduced to about 10% of the space the present process requires. Removal of bone and excess fat prior to chilling can significantly decrease energy costs. Assuming that all bone and excess fat are removed before chilling, total savings in refrigeration could be 50% or more when the edible portion of a 600 pound choice grade beef carcass is compared with an intact carcass (Henrickson, 1975). Henrickson (1981) reported that a 600 pound choice grade carcass, cooled from 100 to 32 F, possesses approximately 31,824 BTU's of energy. The lean portion (62%) would have a total of 21,500, fat 5,630 and bone 4,400 BTU's. When
the bone and surplus fat are removed, the remaining edible portion will have 24,316 BTU or a 24% lower energy requirement. Kastner et al. (1973) reported hot processed sides of beef shrank 2% less than conventionally processed sides measured at 48 h postmortem. Taylor et al. (1981) reported that hot processing and vacuum packaging will reduce evaporative losses and increase product yield. Mandigo (1967 and 1968) stated that hot processing pork carcasses could reduce "in plant" holding time by 21 h for fresh cuts and 117 h for cured cuts compared to conventional processing. Kastner (1983) stated that hot processing would eliminate the need for shrouding, neck pinning, scribing and operations needed to support these functions and reduce labor used in fabrication operations by as much as 25%.

Hot processed meat that is in the prerigor state has functional advantages. Prerigor muscle has a greater water holding capacity which can increase product tenderness, juiciness and yield (Hamm, 1960). The extractability of salt-soluble proteins is also affected by the prerigor state. When blended in a 3% salt solution, prerigor beef yields 48-50% more extractable salt soluble proteins than post-rigor meat (Saffle and Galbreath, 1964 and Acton and Saffle, 1969). Johnson and Henrickson (1970) found prerigor normal-pH meat to contain 69.9% more extractable salt-soluble protein than postrigor normal-pH meat. They limited their conclusions to normal-pH meat because prerigor muscle that has a low-pH has
only 7.3% greater extractability than post-rigor low-pH muscle. Trautman (1964) and Acton and Saffle (1969) both found that prerigor meat had a much greater emulsion capacity than post-rigor meat because of the increased salt-soluble protein extraction.

Disadvantages

Apple (1981) indicated that one disadvantage of hot processing is packaging. The flaccid, sticky nature of prerigor muscle produces a high leaker rate and unattractive cut distortion in vacuum packages. Cross et al. (1981) stated that a major problem with hot processing is our present grading system. At the present time there is no system which exists for determining the quality or yield grades for hot processed meat. Marsh (1981) stated that muscle is in a dynamic state until rigor is established. The muscle will respond to conditions that are imposed on it as if it were living tissue and these conditions will influence the properties of the end-product. When exposed to heat or cold the tissue may undergo heat or cold induced shortening ( Locker and Hagyard, 1963; Davey and Gilbert, 1976). Of much greater importance is the phenomenon of cold shortening ( Locker and Hagyard, 1963), which may be accompanied by massive toughening. Skeletal restraint does not necessarily prevent its occurrence (Marsh, 1981), but certainly does reduce its intensity, so removal of this deterring influence by hot processing clearly increases the likelihood of shortening and
toughening problems. A third potential cause of shortening is thaw rigor. This is the great contraction-like effect, associated with toughening and drip exudation, that accompanies the rapid thawing of meat previously frozen before rigor completion (Marsh and Thompson, 1958; Marsh, 1981). Hamm and Van Hoof (1971) reported that mechanical stimulation such as grinding may also cause fiber shortening.

Tenderness

Tenderness is an important property of meat. Goll et al. (1974) reported that stromal proteins contribute to "background toughness" and myofibrillar proteins are said to create "actomyosin toughness". There are two proposed explanations of how myofibrillar proteins affect tenderness: (1) when the ATP concentration falls too low to maintain dissociation of the myosin heads from the actin filament, the formation of actin-myosin cross-linkages makes the muscle more inextensible and rigid and (2) shortening of the muscle fiber results in increased actin-myosin overlap and greater filament density (Coon, 1982).

Collagen found in connective tissue is the major cause of background toughness. Goll et al. (1963) reported that there is essentially no change in the total amount of muscle collagen as an animal increases in age; however, the percent collagen solubility decreases. This decrease in solubility is the result of increased formation of inter-and intra-molecular crosslinks which give collagen its structural
integrity. Tenderness problems associated with prerigor meat may be primarily myofibrillar in nature (Coon, 1982).

Chilling is a stimulus that can produce contractures in the striated muscles of both the ovine and bovine species (Locker and Hagyard, 1963; Marsh and Leet, 1966). This is called "cold shortening" and it occurs when prerigor muscle is exposed to a temperature near 0°C (Locker and Hagyard, 1963). This "cold shortening" phenomenon is explained by the influence of temperature on the membrane system of the sarcoplasmic reticulum (SR). When prerigor muscle drops below 15°C, the ATP-driven calcium pump of the SR which transports Ca^2+ ions from the sarcoplasm into the SR is thought to be inactivated. Therefore, Ca^2+ ions are released from the sarcotubular system; they activate the myosin adenosine triphosphatase (ATPase) and, consequently, initiate the onset of rigor mortis (Bendall, 1973). The crossbridge formation between actin and myosin which allows these two components to slide past one another, results in the shortening of the sarcomere length. This shortening causes the myofibrillar proteins to overlap and is referred to as myofibrillar toughness (Solomon, 1980). Heat shortening is less of a problem than cold shortening, but it can significantly alter meat tenderness in certain instances. The amount of shortening is highly dependent on the rate of heating. Drainsfield and Rhodes (1975) reported that rapid heating can result in denaturation of
contractile proteins before any shortening can occur, while slow heating will cause severe shortening of prerigor meat.

Marsh and Thompson (1958) reported that severe shortening could occur upon rapid thawing of prerigor, frozen lamb. The more rapid the thaw rate, the more severe the shortening. The shortening is created by freeze damage and (or) temperature inhibition of the calcium pump and results in a rapid flow of $\text{Ca}^{2+}$ into the myofibrillar regions as soon as thawing begins. Behnke and Fennema (1973) found that by back tempering rapidly frozen prerigor muscles at a high sub-freezing temperature, sufficient metabolic activity in the form of ATP depletion and lactate accumulation can occur to prevent muscle fiber shortening associated with thaw rigor.

Temperature Conditioning

One of the most important relationships concerning meat tenderness has been the effect of postmortem temperature decline on muscle sarcomere length (Locker and Hagyard, 1963; Marsh and Leet, 1966; Cassens and Hewbold, 1967). It is this relationship that provided the rationale for the development of high temperature conditioning processes. Locker and Hagyard (1963) reported that the amount of muscle shortening prior to rigor was temperature dependent. The authors observed that bovine muscle excised prerigor was shown to undergo minimal shortening (0 to 20%) if held at 14° to 19° C, intermediate shortening at 37° C and excessive shortening
(40 to 50%) if held below 5 C during the prerigor period. Similar findings have been reported by others (Marsh and Leet, 1966; Cassens and Newbold, 1967;). However, Honikel et al. (1981) reported that the least amount of shortening occurred between 6-10 and 16 C. Considerable fiber shortening and toughening can occur when muscle is exposed to temperatures above or below this range.

Locker (1960) reported that the amount of muscle shortening prior to or during the onset of rigor-mortis affected the ultimate meat tenderness. He reported that muscles which enter rigor mortis in a contracted state were tougher than those in a relaxed state. Marsh and Leet (1966) observed a non-linear relationship while studying the effects of muscle shortening on tenderness. They showed that tenderness decreased with increased shortening from 0 to 30% of the relaxed length, peaked at 35 to 45% shortening and then increased with shortening greater than 50%. Marsh and Carse (1974) reported that the ultimate actomyosin configuration resulting from varying degrees of overlap of myosin and actin filaments explained the shortening/toughness relationship. Further they explain that when muscle fiber is in the highly contracted state (45% shortening), the thick filament (myosin) actually penetrates the Z-line, causing structural damage to the myofilaments. Marsh et al. (1974) stated that when parts of the muscle shortened 50%, some localized super-
contraction is seen to the extent of 80% shortening. It is this structural damage that is believed to account for the increase in tenderness and severe fluid losses from muscle in the highly shortened state.

Prevention of cold shortening and the accompanying toughness is an objective of high temperature conditioning treatments (West, 1979). Marsh and Leet (1966) and Newbold and Harris (1972) state that delaying the exposure of muscle to cold temperatures allows the normal postmortem changes to approach ultimate levels which would remove the effect of cold shortening on meat tenderness. Bendall (1975) suggested that cold shortening was minimized by delaying exposure to cold temperatures until muscle pH reached a value below 6.0 and approximately 50% of the adenosine triphosphate (ATP) had been depleted. The rates of pH decline and ATP depletion are temperature dependent, occurring faster as temperature increases above 10 C (Marsh 1954). Supporting this, Cassens and Newbold (1967) noted that the lower the temperature from 37 to 5 C, the longer beef sternomandibularis muscles took to reach their ultimate final pH. However, at 1 C, the pH dropped faster than at 5 C. Honikel et al. (1981) reported that exposure of beef sternomandibularis muscles to a temperature of 0.5 within the first 4 h postmortem resulted in a faster pH decline than exposure to 7.5, 14 or 30 C. This was believed to be the result of accelerated ATP turnover due to cold shortening, which requires ATP and results
in stimulated glycolytic activity. Jolley et al. (1981) exposed sternomandibularis muscles to a range of temperatures (-1 to 30 °C) within 45 min of stunning. The authors observed accelerated postmortem metabolism as measured by pH decline when temperatures were increased above 10 °C and from cold shortening below 5 °C. This research would substantiate that of Locker and Hagyard (1963) who stated that the optimal temperature for high temperature conditioning would appear to be between 14 °C and 20 °C since this range would exhibit high metabolic activity with a minimal amount of shortening.

In addition to preventing excessive cold shortening in hot processed beef, high temperature conditioning may also accelerate the aging process. Fukazawa and Yasui, (1967) stated that tenderization found during aging was caused by the degradation of Z-lines within the sarcomeres. Olson et al. (1976) believed that the aging tenderness was attributed to myofibrillar fragmentation. Henderson et al. (1970) observed that Z-line degradation in excised bovine muscle occurred much faster at temperatures above 25 °C than at lower temperatures. Olson et al. (1976) reported myofibril fragmentation was faster in LD and ST muscles held at 25 °C when compared to muscles held at 2 °C. Olsen et al. (1977) and Parrish (1977) have suggested that the accelerated fragmentation observed with high temperature conditioning results from the increased activity of the protease calcium activated factor. Parrish (1977) proposed that this endogenous muscle
protease has been the agent responsible for myofibril fragmentation, Z-line degradation and the disappearance of troponin-T and the concurrent appearance of a 30,000-dalton component. Locker et al. (1977) indicated that gap filaments are modified by aging and that higher temperature (37°C) may weaken the actin attachment to Z-lines.

Dutson et al. (1975) provided additional evidence for accelerated aging when they observed that muscles which were prevented from shortening by the Tenderstretch procedure (Hostetler et al. 1972) and subjected to high temperature conditioning were more tender than muscles that were subjected only to Tenderstretch. Locker and Daines (1976) raised the temperature of excised cold shortened muscle to 37°C during the final stages of rigor and reported that this high temperature nullified the toughness of cold shortened muscles without affecting the amount of shortening. Moeller et al. (1976) and (1977) suggest that the high temperature, low pH conditions found in conditioned muscles would be conducive to disruption of lysosomal membranes and the concurrent release of proteolytic enzymes into the muscle. Yates (1977) stated that lysosomal proteolysis resulted in cleavage of the myosin molecule and, thus, disruption of the actin-myosin interaction. Based on a study by Wu et al. (1981), it was concluded that high temperature conditioning (37°C), resulted in a greater release of lyso-
somal enzymes (from lysosomes) and an increase in collagen solubility.

While studying the effects of early-postmortem cooling rate on beef tenderness, Lochner et al. (1980) came to some interesting conclusions. Their results indicated that (1) except in very rapidly chilled, lean carcasses, cold shortening is not a significant determinant of tenderness; (2) the enhanced tenderness of slowly chilled beef is not due primarily to the relatively prolonged avoidance of shortening-inducive temperatures but to the accompanying retardation of cooling during the first 2-4 h postmortem, when muscle temperatures are still above those associated with cold shortening. Marsh et al. (1981) reported similar results as they showed that beef tenderness is strongly influenced by muscle temperature in the first hours after slaughter. Maintenance of about 37 C within the longissimus muscle during this time results in appreciable tenderness enhancement. Marsh et al. (1981) concluded that it is wrong to assume that aging commences only after the full achievement of rigor-mortis as reported by Davey and Gilbert (1976) and Chrystall and Devine (1980). Provided that temperature and pH of the musculature are maintained close to their in vivo values for 2-4 h postmortem, quality enhancement is greatest and fastest during the very early post-slaughter period, while the tissue is still in a strictly prerigor condition.
These results would directly conflict with those of Locker and Daines (1976). Marsh et al. (1981) further concludes that the tenderizing is due primarily to an enzyme or enzyme system that is highly (perhaps optimally) active at a near neutral pH and a temperature of about 37°C. Marsh (1983) postulates that it is the combination of a relatively high pH and a high temperature, rather than either of them separately, that is responsible for the rapid tenderizing in early-postmortem high temperature conditioned beef. Debate continues on the possible mechanisms that exist to explain high temperature conditioning affect on meat tenderness. Certainly more research is required in this area.

Hot Processing Systems

Most hot processing systems have relied on carcass and muscle or muscle system conditioning at elevated temperatures or the conventional aging of hot processed muscle and muscle systems to prevent or minimize any effects of pre-rigor excision and cold shortening in beef steaks and roasts. Schmidt and Gilbert (1970) hot processed one side of six beef carcasses to obtain muscle portions within 2 hr postmortem. Following fabrication, the excised muscles were vacuum packaged and conditioned at approximately 15°C until either 24 or 48 h postmortem. Compared with counterparts excised from control sides, chilled at 9°C until 24 h postmortem, the hot processed samples were generally equal or superior to the controls in shear force and taste panel evaluations. Schmidt
and Keman (1974) hot processed muscle portions from one side of six beef carcasses at approximately 1 h postmortem. The excised muscle portions were stored at about 7°C for approximately 4 h, then were placed in a 1°C cooler overnight. The controls were cut from the conventionally chilled (1°C) carcass sides at 8 days postmortem. Differences in shear force and taste panel means were not significant. Taylor et al. (1980) excised and vacuum packaged subprimals from steer sides within 1 to 2 h postmortem. At 3 h postmortem the packaged cuts were conditioned at 10°C for 9 h and chilled at 1°C. The control sides were conditioned at 15°C for 7 h and chilled at 1°C until 48 h postmortem whereupon subprimals were removed. The control and hot processing treatments were equivalent in organoleptic qualities but hot processed cuts had more desirable color.

As an alternative to conditioning subprimals, beef sides have been hot processed after a conditioning period. Kastner et al. (1973) assumed that a conditioning time would minimize or eliminate tenderness problems that might be associated with prerigor excision. Kastner et al. (1973) reported that sides held intact for 8 h post-mortem, then fabricated, produced hot processed cuts of equal or superior value than the conventional treatment when considering yield, tenderness, color and flavor. Henrickson et al. (1974) stated that conditioning sides for only 3 h did not greatly reduce the tenderness of the product. Falk et al. (1975)
reported that sides conditioned at 16°C for 3 h exhibited minor differences in tenderness when compared to conventionally chilled sides. They suggest that the slight tenderness differences between hot-boned muscles and conventionally chilled muscles are not practically significant. Kastner and Russell (1975) suggest that if sides to be hot processed were held until 8 h postmortem the hot processed method was comparable to the conventional method. Kastner et al. (1976) reported similar results and added that conditioning beef sides at 16°C for up to 10 h post-mortem gave products with acceptable bacterial counts compared to conventionally chilled carcasses. Drainsfield et al. (1976) used a combination of the previous hot processing methodology. Sides were maintained at ambient temperatures for 3 h post-mortem and the resulting hot processed muscles were vacuum packaged and conditioned at 10°C for 24 h. When compared to sides from conventionally chilled after conditioning at ambient temperatures for 5 h postmortem, in general, hot processing resulted in equal eating quality. The combination of high temperature conditioning and hot processing together help to ensure a product that is equal or superior in palatability and yield to their control counterparts. The combination also produces a desirable product from an appearance and shelf life standpoint (Cross, 1980; Kastner, 1981).
Restructured Products

Pepper and Schmidt (1975) found restructured beef rolls from hot processed muscle to be comparable to those from conventionally chilled and processed carcasses. Huffman and Cordray (1979) produced restructured pork chops from pre-rigor and post-rigor pork. Restructured chops produced from either processing method were found to be superior to intact pork chops. However, the color of restructured products was less desirable than intact pork loin chops. On the contrary, Seideman et al. (1980) found restructured steaks formulated from hot processed top rounds to be less desirable than counterparts from conventionally chilled and processed carcasses when considering juiciness, texture, flavor and overall satisfaction ratings. However, the hot processed steaks were more desirable when raw color was evaluated.

Coon (1982) concluded that with appropriate modifications (such as tempering frozen logs at -3 C), the restructuring process can allow for the incorporation of prerigor beef into sectioned and formed beef steaks. In this experiment, the bind and tenderness of restructured, prerigor beef steaks were enhanced by increasing salt, mix time and(or) temper time. Marriott et al. (1983) found no consistent differences in objective or subjective sensory traits exhibited by restructured chops from prerigor and post-rigor pork.
METHODOLOGY

Experiment #1. Characteristics of conventionally chilled and prerigor conditioned bovine muscle from intact and castrated males.

Delayed chilling. South Devon steers (n=10) and bulls (n=10) were slaughtered at 16 mo of age with left sides receiving a 4 h delayed chill (DC) treatment (12.8°C) and subsequently chilled at 2°C. Rib tissues from the 10-12th rib sections were removed 7 d, postmortem, vacuum packaged and stored at -25°C for further analyses. Right sides were conventionally chilled (CC) at 2°C and otherwise treated identical to the DC treatment.

Carcass data. Carcass data were collected 48 h postmortem from right sides of South Devon steers (n=10) and bulls (n=10). Data consisted of marbling and maturity scores, final quality grades, adjusted subcutaneous fat thickness, estimated percentage kidney, pelvic and heart fat and longissimus area. Lean color and firmness scores at the 12th rib interface were determined by experienced personnel using a 7-point scale for each factor (1=extremely soft or very dark red; 2=very soft or dark red; 3=soft or moderately dark red; 4=slightly soft or cherry red; 5=moderately firm or light cherry red; 6=firm or very light cherry red; 7=very firm or dark pink).
Carcass temperature. Carcass temperature was monitored using an IT660 Probe (Electromedics, Inc., Englewood, Colorado). Temperatures were taken from the center of the longissimus at the 7-8th rib region.

pH. Muscle samples were removed from the longissimus muscle in the 6-8th rib region at 1, 2, 4, 8 and 24 h postmortem. Five grams of frozen, powdered meat sample were combined with 50 ml of 0.005 M iodoacetate and homogenized for 1 min in a 250 ml blender jar. The pH was measured with a Beckman 3560 Digital pH Meter (Beckman Industries, Inc., Irvine, California).

R-value. R-values were determined using the procedure of Coon (1982) with slight modifications (Appendix, Procedure 1) on four samples at a time in duplicate. Muscle samples used were removed from the longissimus muscle in the 6-8th rib region at 2, 4, 8 and 24 h postmortem. The modification in the procedure was due to centrifugation capacity of eight (50 ml) tubes at one time. The Beckman 3560 Digital pH Meter was used to adjust pH. Spectrophotometer readings were acquired from a Beckman DU spectrophotometer.

Sarcomere length. Sarcomere lengths were determined on all treatments using a procedure adopted from Cohen et al. (1982) (Appendix, Procedure 4). A Spectra Physics Laser with a He-Ne lamp (wavelength = 632.8 nm) was used.
Cook loss and Warner-Bratzler Shear tests. Steaks were thawed for 24 h at 2°C prior to cooking. Steaks (2.54 cm) were cooked to an internal temperature of 70°C on a Farberware electric "open hearth" broiler. Copper constantan thermocouples were used to monitor steak temperatures. Percentage cook losses were determined by subtracting cooked steak weight from raw steak weight and then dividing by raw steak weight and multiplying by 100. Steaks were cooled at room temperature for 1 h prior to Warner-Bratzler shear tests. Seven, 12.7 mm cores, were removed from each steak and sheared one time.

Sensory evaluation. Panelists selection was based upon interest, availability and consistency of evaluation of the group during ten training sessions. During training, score sheets (figure 1) and instructions (figure 3) were outlined. A variety of intact muscle tissues, cooking times and temperatures were used to provide examples over the entire scale of characteristics judged. Group discussions were held after each training session to refine sensory impressions of the panelists. Eight individuals were selected to participate on the panel. Panelists were served in individual booths under red lights. Three sessions were held each week with five samples being evaluated at each session. Each sample was evaluated using an 8-point scale with 8 being extremely tender, juicy, intense flavor or no connective tissue residue and 1 being extremely tough, dry,
bland or abundant connective tissue residue. Steaks were cooked at to an internal temperature of 70°C in a convention oven (Toastmaster, Algonquin, Illinois). Copper-constantan thermocouples were used to monitor steak temperatures. Samples were held at a constant 50°C using the double boiler system described by Caporaso (1978).

Statistical analysis. Results were analyzed using a 2 sex by 2 chill treatment factorial arrangement of treatments in a split plot design (Steel and Torrie, 1980) with sex as the main effect and chill treatments as the subplots. Ten replications were used with replications being represented by individual animals. Data was analyzed using least-squares equations. The Statistical Analysis System (1982) (SAS Institute, Raleigh, North Carolina) was used to calculate treatment means and detection of treatment differences.
Experiment #2. The effects of sex and delayed chill on the biophysical and organoleptic properties of chunked and formed beef steak.

Meat source. South Devon steers (n=10) and bulls (n=10) were slaughtered at 16 mo of age with the chucks from the left sides boned and trimmed following a 4 h (12.8°C) delayed chill (DC) treatment while the chucks from the right sides were boned following a 48 h (2°C) conventional chill (CC) period. All lean and fat used in the steak formulation originated from the chuck and plate.

Steak preparation. Boneless chucks had heavy connective tissue sinews removed manually and were needle tenderized (Ross TC 700, Ross Industries, Midland, Virginia; 2.54 cm advance setting) three times. Tenderized chuck was ground through a 2.54 cm plate (Hobart Mixer-Grinder; Hobart Manufacturing Co., Troy, Ohio). The fat source (chuck and plate) was fine flaked through an Urschel Comitrol (model 3600) using a 120 head (Urschel Laboratories, Valparasio, Indiana) prior to mixing. Each chuck was used to prepare a 9.1 kg batch formulated to an approximated 15% fat content. Lean tissue was estimated to contain 6-9% fat, thus 10% fat (by weight) was added to the lean in order to approximate a 15% fat content. Fat and salt (0.5%) were added during the first 30 s of blending and batches were mixed (Leland Food Mixer 100 DA, Leland Detroit Mfg. Co., Detroit, Michigan) for 10 min. Three, 1 kg samples, were removed from each batch,
hand-formed in Cryo-Vac bags and vacuum packaged. The logs were crust frozen in a -30 °C freezer to an internal temperature of -3 °C, then tempered at -3 °C for 12 h. Frozen logs were pressed 1.72 MPA (250 lbs/in²) using a cylindrical tube (62 cm) and a Carver laboratory press. Pressed logs were cleaved (Hobart Commercial Slicer 1712; Hobart Manufacturing, Troy, Ohio) into 2.54 cm thick steaks, vacuum packaged and frozen at -25 °C for later analyses.

Proximate analyses. Raw steaks, representative of each treatment, were analyzed in duplicate for percentage moisture, fat, protein and ash using a modification of AOAC (1975) standard procedures. One sample was used to determine moisture (oven drying, AOAC 1975), fat (soxhlet, AOAC 1975) and protein (Kjeldahl, AOAC 1975). A separate sample was used to determine percentage ash (AOAC 1975).

TBA analysis. The thiobarbituric acid (TBA) procedure of Tarladgis et al. (1960) was used (Appendix, Procedure 2) was adopted from Tarladgis et al. (1960). TBA values were determined at one week and 90 d following steak preparation. Duplicate values were measured for each treatment at each test time.

Steak color. Fabricated steaks were evaluated with a Bausch & Lomb Spectronic 20 equipped with the Color Analyzer Reflectance Attachment. Each replicate of each treatment was measured four times (2 readings for each of 2 steaks). The reflectance attachment measured a rectangular 2 x 8 mm
area on the meat surface. Major fat areas were avoided. A magnesium block was used for 100% reflectance. Objective color measurements were determined using % reflectance at 630 nm minus % reflectance at 580 nm (van den Oord and Wesdrop, 1971). Reflectance at 630 nm is high for oxymoglobin and low for metmyoglobin. The reverse is true at 580 nm. Therefore a higher value indicates a brighter color.

Cooking procedures

All steaks used for sensory evaluation, cook loss determinations and Lee-Kramer analyses were cooked to an internal temperature of 70 C in a convention oven (Toastmaster, Algonquin, Illinois). Internal temperature was monitored using copper-constantan thermocouples inserted into the center of the steaks. Steaks were blotted dry and cooking losses were determined by weighing before cooking and 1 h following cooking after cooling. Total cook loss was partitioned into evaporative and drip losses (Appendix, Procedure 3). Following cook loss determinations, steaks were used for Lee-Kramer shear tests. Sensory evaluation samples were held at a constant 50 C using the double boiler system described by Caporaso (1978).

Lee Kramer

Steaks were trimmed to 45 x 45 mm and weighed. The Lee-Kramer shear press (Model SP-11) was equipped with a 1365 kg manual dial proving ring with a 20 s cell speed. Shear force was determined by dividing the peak force by the sample
weight and multiplying by 10 (kg force/10 g sample).

Sensory evaluation

Panelist selection was based upon interest, availability and consistency of evaluation of the group during 10 training sessions. During training, score sheets (figure 2) and instructions (figure 3) were outlined. A variety of intact and restructured muscle tissues, cooking times and temperatures were used to provide examples over the entire scale of characteristics judged. Group discussions were held after each training session to refine sensory impressions of the panelists. Eight individuals were selected to participate on the panel. Panelists were served in individual booths under red lights. Each sample was evaluated for tenderness, juiciness, flavor, bind and connective tissue residue. Three sessions were held each week with five samples being evaluated at each session. Samples were evaluated using an 8-point scale with 8 being extremely tender, juicy, intense flavor, extreme bind or no connective tissue residue and 1 being extremely tough, dry, bland, no bind or abundant connective tissue residue.

Statistical analysis. Results were analyzed using a 2 sex by 2 chill treatment factorial arrangement of treatments in a split plot design (Steel and Torrie, 1980) with sex as the main effect and chill treatments as the subplots.
Ten replications were used with replications being represented by individual animals. The Statistical Analysis System (1982, SAS Institute, Raleigh, North Carolina) was used to calculate treatment means and detection of treatment differences.
LITERATURE CITED


Andres, C. 1982. FDA estimates 40% of food will carry sodium content label by spring. Food Processing Feb. p. 75.


Siegel, D.G., Church, K.E. and Schmidt, G.R. 1979b. Gel structure of non-meat proteins as related to their ability to bind meat pieces. J. Food Sci. 44:1276.


CHARACTERISTICS OF CONVENTIONALLY CHILLED AND PRERIGOR CONDITIONED BOVINE MUSCLE FROM INTACT AND CASTRATED MALES.

ABSTRACT

South Devon bulls (n=10) and steers (n=10) were slaughtered at 16 mo of age. The right sides were conventionally chilled (CC) at 2 C while the left sides were delayed chilled (DC) for 4 h at 12.8 C and subsequently moved to the 2 C cooler. Bulls exhibited heavier carcasses, larger longissimus (LD) area, less subcutaneous fat and lower USDA yield grades. Steers possessed higher marbling scores and more desirable lean texture. Bulls and DC sides exhibited higher LD temperatures 2 and 4 h postmortem. Bulls and CC sides tended to have higher 2 and 4 h pH values. R-values and cooking losses were not affected by sex or chill treatment. Sex had no affect on Warner-Bratzler (WB) values; however, DC steaks had lower WB values than steaks from CC sides. Steers possessed slightly longer LD sarcomeres but no difference was observed between chill treatments. Sensory panelists judged steers to be superior in tenderness, flavor, juiciness and connective tissue residue. Steaks from CC sides were rated more tender than steaks from DC sides, but no differences were detected for the other sensory traits.
INTRODUCTION

One of the most important relationships concerning meat tenderness has been the effect of postmortem temperature decline on muscle sarcomere length (Locker and Hagyard, 1963; Marsh and Leet, 1966; Cassens and Newbold, 1967). Post-slaughter chilling is a stimulus that can produce contractures in the straited muscles of both the ovine and bovine species (Locker and Hagyard, 1963; Marsh and Leet, 1966). This phenomenon is called "cold shortening" and it occurs when prerigor muscle is exposed to temperatures near 0°C (Locker and Hagyard, 1963). Prevention of cold shortening and the accompanying toughness is an objective of high temperature conditioning (HTC) (West, 1979).

In addition to preventing fiber shortening, HTC may accelerate the aging process. Dutson et al. (1977) and Moeller et al. (1976 and 1977) concluded that increased tenderness associated with HTC muscle may be caused by an increased activity of lysosomal cathepsins. Lochner et al. (1980) and Marsh et al. (1981) concluded that increased tenderness associated with delayed chill beef was not due to the prevention of cold shortening but rather the maintenance of high temperature and high muscle pH for 2-4 h postmortem.

Carcass fat cover may serve as a muscle insulator preventing rapid chilling of prerigor muscle, thus, preventing cold shortening. But, consumer resistance to excessive fat in red meat and the role of producer economics will cause
leaner livestock to be marketed which may be subject to cold shortening (Crouse and Seideman, 1984).

Jacobs et al. (1977) reported that on a boneless basis, bull carcasses contained 58% less crude fat and 23% more crude protein than steer carcasses. However, research by (Field, 1971; Arthaud et al., 1977 and Gregory et al., 1983) has shown that bull meat is less tender and generally receives lower overall acceptability ratings when compared to steers. The potential for intact males to be an efficient source of lean beef hinges on the ability to enhance its muscle tenderness. Therefore, the objectives of this study were to determine the effects of delayed chilling (4 h, 12.8°C) vs conventional chilling (2°C) on carcass characteristics and the biochemical and sensory properties of meat obtained from South Devon bulls and steers.
EXPERIMENTAL PROCEDURES

Delayed Chilling

South Devon steers (n=10) and bulls (n=10) were slaughtered at 16 mo of age with left sides receiving a 4 h delayed chill treatment (12.8 C) then chilled at 2 C. Right sides were conventionally chilled at 2 C. Rib tissue from the 10-12th rib section was removed seven days postmortem, vacuum packaged and stored at -25 C for further analyses.

Carcass Data

Carcass data (USDA, 1976) were collected 48 h post-mortem from the right sides of South Devon steers (n=10) and bulls (n=10). Data collected included marbling and maturity scores, final quality grades, adjusted subcutaneous fat thickness, estimated percentage kidney, pelvic and heart fat and longissimus muscle area. Lean color and firmness scores at the 12th rib interface were determined using a 7-point scale. Seven was very firm or very dark pink and one was extremely soft or very dark red.

Carcass Temperature

Carcass temperature was monitored using an IT 660 Probe (Electromedics, Inc., Englewood, Colorado). Temperatures were taken from the center of the longissimus at the 7-8th rib region at 1, 2, 4, 8 and 24 h postmortem.
pH and R-values

Muscle samples were removed from the longissimus muscle in the 6-8 rib region at 1, 2, 4, 8 and 24 h post-mortem and used in the pH and R-value analyses. Muscle pH was determined by adding 5 g of meat sample to 50 ml of 0.005 M iodoacetate solution, homogenizing in a 250 ml blender for 1 min, and measuring pH. The method to determine R-values was a modification of that used by Coon et al. (1983). The R-value determination involved homogenation of 4 g of frozen muscle in 40 ml of 0.9 M perchloric acid (room temperature). The resultant slurry was centrifuged for 10 min at 3000 x g. The supernatant was filtered through Whatman no. 1 filter paper and the pH was adjusted to pH 6.0-6.5 using 2.0 M potassium hydroxide. After chilling in an ice bath for 30 min, the solution was again filtered through Whatman no. 1 filter paper. The filtered extract was combined with a phosphate buffer (pH 6.5, 0.1 M potassium phosphate) using 0.3 ml of extract and 8.7 ml of buffer. This solution was thoroughly mixed and the absorbance was measured at 250 and 260 nm. The R-value was defined as the ratio of absorbance at 250 nm over the absorbance at 260 nm (Honikel and Fischer, 1977).

Cook Loss and Warner-Bratzler Analyses

Steaks used for cook loss determinations and Warner-Bratzler shear analyses were cooked to an internal temperature of 70 C on an open hearth Farberware grill. Steaks were
thawed at 2°C for 24 h prior to cooking. Internal temperature was measured by copper-constantan thermocouples inserted into the center of the steaks. Percentage cook loss was determined by subtracting cooked steak weight from raw steak weight and then dividing by raw steak weight. Steaks were cooled at room temperature for 1 h prior to WB shear tests. Seven, 1.27 cm cores were removed from each 2.54 cm steak. Samples were sheared perpendicular to the long axis of the muscle fibers.

Sarcomere Length

Sarcomere length was determined using a laser diffraction technique described by Cohen et al. (1982). A small piece of LD muscle was cut with known orientation of the fibers. Ten individual fibers were teased out and mounted between a glass slide and a cover slip using a drop of 2% glutaraldehyde. The sample was placed in the path of the laser beam in order to produce diffraction bands on a screen. Sarcomere lengths were calculated using the following formula:

\[ d = \left( \frac{632.8 \times 10^{-6} \text{ um}}{S} \right) \times (D) \]

where \( d \) is equal to the sarcomere length; \( 632.8 \times 10^{-6} \) is the wavelength of radiation in microns; \( D \) is the distance in millimeters between the specimen-holding device and the screen; \( S \) is the distance (mm) between the 0th and 1st order
diffraction band. Throughout this experiment D had a constant value of 100 mm.

Sensory Evaluation

Panelist selection was based upon interest, availability and consistency of evaluation during ten training sessions. During training, score sheets and instructions were outlined. A variety of intact muscle tissues, cooking times and temperature were used to provide examples over the entire scale of characteristics judged. Group discussions were held after each training session to refine sensory impression of the panelists. Eight individuals were selected to participate on the panel. Panelists were served in individual booths under red lights. Three sessions were held each week with five samples being evaluated at each session. Each sample was evaluated using an 8-point scale. An 8 was defined as extremely tender, juicy, intense flavor or no connective tissue residue and 1 was extremely tough, dry, bland or abundant in connective tissue residue. Steaks were cooked to an internal temperature of 70°C in a convection oven (Toastmaster, Algonquin, Illinois). Copper-constantan thermocouples were used to monitor steak temperatures. Samples were held at a constant 50°C during serving using a double boiler system as described by Caporaso (1978).

Statistical Analyses

Analysis of variance was calculated using a 2 sex by 2 chill treatment factorial arrangement of treatments in a
split-plot design as described by Steel and Torrie (1980) with sex as the main effect and chill treatments as the subplots. Ten replications were used with replications being represented by individual animals.
RESULTS AND DISCUSSION

Carcass Traits

Means and standard errors for carcass traits are presented in table 1. Intact males possessed heavier (P<0.05) carcass weights, larger (P<0.01) longissimus (LD) muscle areas and exhibited significantly (P<0.01) less 12th rib subcutaneous fat than steers. Therefore, bulls had significantly (P<0.01) lower USDA yield grades; however, steers displayed higher (P<0.05) marbling scores. The effects of castration on carcass traits are in general agreement with other reports (Arthaud et al., 1969, 1977; Field, 1971; Jacobs et al., 1977a). Castrates exhibited a firmer (P<0.01) lean texture which is consistent with (Field, 1971; Seideman et al., 1982). The lack of a significant sex effect on color scores of lean is generally consistent with results of Tennesson and Price (1980).

Carcass Temperature

Longissimus mean temperatures and standard errors for sex and chill treatments are presented in table 2. Bulls had a slower rate of carcass temperature decline in the LD thus possessing higher (P<0.01) temperatures at 2 and 4 h post-mortem. The larger LD muscles of bulls (table 1) probably resulted in a slower chill rate which is in agreement with (Couse et al., 1983).
DC sides exhibited significantly ($P<0.01$) higher LD temperatures at 2 and 4 h postmortem. Lochner et al. (1980) and Marsh et al. (1981) reported that tenderness improvement caused by higher chill temperature is due, not to the maintenance of temperatures above the cold shortening range for the first 10-12 h postmortem, but rather to the slow decline of temperatures during the first 2-4 h postmortem. However, LD temperatures of all sides in this study at 4 h postmortem were lower than the 37°C temperature suggested by Marsh et al. (1981) as necessary to promote high temperature conditioning effects.

Chucks were removed from all DC sides at 4 h postmortem and used in other research. That removal confounded temperature data as seen in the 8 and 24 h values in table 2. Because removal of the chucks may have affected LD pH and R-values after 4 h postmortem, only data through 4 h will be presented.

**pH and R-values**

pH and R-values were monitored as a measure of postmortem glycolytic rate and their means and standard errors are presented in table 3. Bulls tended to have higher LD pH values with a significant ($P<0.05$) difference at 2 h postmortem. One would have expected a higher glycolytic rate and more rapid pH decline in the higher temperature bull LD.
Seideman et al. (1982) suggested that because of their temperament, bulls may be more easily stressed than steers resulting in low quantities of glycogen. Higher pH values of bulls may reflect lower glycogen quantities.

DC longissimus muscles exhibited a trend toward lower pH values at 2 and 4 h postmortem. DC longissimus muscle would have been expected to have increased glycolytic activity and lower pH values due to their elevated temperature, early postmortem.

In the normal progression of rigor, the adenine nucleotides (ATP, ADP and AMP) are converted to inosine monophosphate, inosine and hypoxanthine. By extracting these compounds from muscle and measuring their relative concentrations using absorbance maxima (adenine nucleotides maxima approximately 260 nm; inosine compounds maxima approximately 250 nm), the ratio of high energy compounds to their breakdown products can be obtained (Coon et al., 1983). An increasing R-value (absorbance at 250 nm divided by absorbance at 260 nm) would indicate a decrease in the relative amount of ATP. Neither sex nor chill treatment affected (P>0.05) R-value change. R-values did increase over time indicating a disappearance of the adenine nucleotides from 2 to 4 h postmortem.

Sarcomere Length and Warner-Bratzler Analyses

Meat tenderness is determined by two components of muscle, namely connective tissue (principally collagen) and
the myofibrillar proteins involved in the contractile process (Marsh, 1977). Collagen crosslinking increases with age such that the older the animal, the stronger the collagen fibrils and the less tender the meat. The contractile proteins change very little with age; however, shortening of the myofibrils will cause a decrease in sarcomere lengths which will result in less tender meat. Both components can be analyzed, but sarcomere length measurements are obtained more quickly and easily than collagen determinations.

Castrates had longer (P<0.05) LD sarcomeres than intact males (table 4). Chill treatment had no (P>0.05) affect on LD sarcomere length. Sarcomeres lengths reported in this study are similar to those presented by Will et al. (1979) but shorter than those reported by Hostetler et al. (1975).

Steers possessed longer sarcomeres and this difference was reflected in lower WB shear values but the difference was small and not significant (P<0.05). WB values were .33 kg greater for meat from bulls than from steers (table 4). This result is consistent with Field (1971) who observed that in seven of seven studies reviewed, bull beef had higher shear force values than steer beef; however, the amount of the difference was never greater than .65 kg/1.27 cm core.

DC longissimus steaks exhibited lower (P<0.05) WB shear values (table 4) than CC steaks. This result differs
from Crouse et al. (1983) who reported that high temperature conditioning (16 C vs 2 C) did not affect WB shear values; however, this result is consistent with that of Lochner et al. (1980) and Marsh et al. (1981) who also reported that high temperature conditioning improved meat tenderness.

Cooking and Sensory Characteristics

No differences were observed in cooking losses due to sex or chill treatment (table 4). Crouse et al. (1983) stated that bulls had greater (P<0.01) cooking losses than steers; however, chill treatment had no affect on cooking loss.

Sensory panel means and standard errors are presented in table 5. Bulls were judged by panelists to be less (P<0.01) tender than steers. This is consistent with reports by Ntunde et al. (1977) and Gregory et al., (1983). Reagan et al. (1971) stated that steaks from bull carcasses were considerably more variable in tenderness than were those from steer carcasses. However, in this study, bulls were only slightly more variable in tenderness than steers.

Differences in tenderness between bulls and steers were reflected in differences between sensory ratings (P<0.01) for the amount of connective tissue residue. Bulls were judged by panelists to have considerably (P<0.01) more detectable connective tissue than steers. Sensory detectable connective tissue residue was also highly correlated with overall tenderness (r=.68). This indicates that variation in
tenderness between sexes is primarily due to the sensory perception of connective tissue. Crouse et al. (1983) also reported that the variation in tenderness associated with sex condition was related to the connective tissue component of meat rather than the myofibrillar component.

DC steaks had lower (P<0.05) initial and overall tenderness scores than CC steaks. These apparent tenderness differences caused by sex and chill treatment were not consistently reflected by the WB shear values (table 4). Perhaps the WB shear and sensory panelists measure different components of tenderness. There was no (P<0.05) difference in connective tissue residue (table 5) as affected by chill treatment.

Bulls expressed significantly (P<0.01) lower flavor and juiciness scores than steers. In contrast, Field (1971) and Jacobs et al. (1977b) reported little difference in flavor or juiciness as affected by sex condition. However, Forrest (1975) reported that bulls were less juicy, less flavorful and received lower overall palatability scores than steers. Crouse et al. (1983) observed that bulls possessed lower sensory flavor scores but found no difference in juiciness. Sink et al. (1983) reported higher expressable juice values for bulls than steers. There was no significant (P>0.05) difference in sensory panelists perception of flavor
or juiciness between either chill treatment. Crouse et al. (1983) observed that high temperature conditioning (16 °C) promoted a more intense flavor than did conventional chilling (2 °C); however, no difference in juiciness was detected.

CONCLUSION

Results of this study indicate that bulls have leaner, heavier muscled carcasses that produce steaks less palatable than steers. Sensory panel scores indicate that connective tissue was highly associated with tenderness. This suggests that variation in tenderness was affected primarily by connective tissue. Savell et al. (1982) observed that blade tenderization increased the palatability of bull steaks. Perhaps, blade tenderization used in conjunction with delayed chilling may produce intact male beef of acceptable palatability.
### TABLE 1. CARCASS DATA MEANS AND STANDARD ERRORS FOR SOUTH DEVON BULLS AND STEERS

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carcass weight, kg</td>
<td>339.3*</td>
<td>314.30*</td>
<td>8.79</td>
</tr>
<tr>
<td>REA</td>
<td>88.89**</td>
<td>74.91**</td>
<td>3.20</td>
</tr>
<tr>
<td>Fat thickness, cm</td>
<td>.62**</td>
<td>.96**</td>
<td>.08</td>
</tr>
<tr>
<td>KPH, %</td>
<td>2.05</td>
<td>2.4</td>
<td>.14</td>
</tr>
<tr>
<td>Yield grade</td>
<td>2.03**</td>
<td>2.91**</td>
<td>.81</td>
</tr>
<tr>
<td>Marbling score</td>
<td>slight 67*</td>
<td>small 08*</td>
<td>14.94</td>
</tr>
<tr>
<td>Firmness</td>
<td>4.9**</td>
<td>5.9*</td>
<td>.21</td>
</tr>
<tr>
<td>Color</td>
<td>2.7</td>
<td>3.2</td>
<td>.28</td>
</tr>
</tbody>
</table>

1. 7-point scale: 1=extremely soft, 7=very firm.

2. 7-point scale: 1=very dark red, 4=cherry red, 7=very dark pink.

* Means with like superscripts in the same row differ significantly (P<0.05).

** Means with like superscripts in the same row differ significantly (P<0.01).
**TABLE 2. EFFECT OF SEX AND CHILL TREATMENT ON POSTMORTEM TEMPERATURE DECLINE IN THE LONGISSIMUS DORSI**

<table>
<thead>
<tr>
<th></th>
<th>1 h</th>
<th>2 h</th>
<th>4 h</th>
<th>8 h</th>
<th>24 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td>38.6</td>
<td>35.9**</td>
<td>30.2**</td>
<td>20.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Bulls</td>
<td>38.6</td>
<td>37.1**</td>
<td>32.1**</td>
<td>21.1</td>
<td>4.30</td>
</tr>
<tr>
<td>SE</td>
<td>.21</td>
<td>.25</td>
<td>.27</td>
<td>.27</td>
<td>.17</td>
</tr>
<tr>
<td>DC&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.7</td>
<td>36.9**</td>
<td>32.6**</td>
<td>21.2</td>
<td>3.1**</td>
</tr>
<tr>
<td>CC&lt;sup&gt;b&lt;/sup&gt;</td>
<td>38.5</td>
<td>36.0**</td>
<td>29.7**</td>
<td>20.7</td>
<td>5.5**</td>
</tr>
<tr>
<td>SE</td>
<td>.11</td>
<td>.16</td>
<td>.10</td>
<td>.17</td>
<td>.12</td>
</tr>
</tbody>
</table>

**Means with like superscripts in the same column differ significantly (P<0.01).**

<sup>a</sup> DC: Delayed Chill.

<sup>b</sup> CC: Conventional Chill.
<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>DC</th>
<th>CC</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 h</td>
<td>6.80</td>
<td>6.73</td>
<td>.08</td>
<td>6.78</td>
<td>6.76</td>
<td>.03</td>
</tr>
<tr>
<td>2 h</td>
<td>6.63*</td>
<td>6.42*</td>
<td>.07</td>
<td>6.52</td>
<td>6.54</td>
<td>.03</td>
</tr>
<tr>
<td>4 h</td>
<td>6.35</td>
<td>6.19</td>
<td>.08</td>
<td>6.24</td>
<td>6.32</td>
<td>.03</td>
</tr>
<tr>
<td><strong>R-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 h</td>
<td>1.29</td>
<td>1.25</td>
<td>.012</td>
<td>1.27</td>
<td>1.27</td>
<td>.010</td>
</tr>
<tr>
<td>4 h</td>
<td>1.38</td>
<td>1.34</td>
<td>.011</td>
<td>1.35</td>
<td>1.37</td>
<td>.013</td>
</tr>
</tbody>
</table>

a  
DC: Delayed Chill.

b  
CC: Conventional Chill.

* Means with like superscripts in the same row differ significantly (P<0.05).
TABLE 4. EFFECT OF SEX AND CHILL TREATMENTS ON WARNER-BRATZLER SHEAR VALUES, SARCOMERE LENGTHS AND COOK LOSSES

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>a</th>
<th>b</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sarcomere length, μm</td>
<td>1.53*</td>
<td>1.64*</td>
<td>.02</td>
<td>1.57</td>
<td>1.60</td>
<td>.02</td>
</tr>
<tr>
<td>WB, kg/1.27 cm</td>
<td>7.12</td>
<td>6.79</td>
<td>.25</td>
<td>6.73*</td>
<td>7.18*</td>
<td>.11</td>
</tr>
<tr>
<td>Cooking loss, %</td>
<td>20.9</td>
<td>23.4</td>
<td>1.26</td>
<td>24.1</td>
<td>20.3</td>
<td>.9</td>
</tr>
</tbody>
</table>

a  DC: Delayed Chill.
b  CC: Conventional Chill.
* Means with like superscripts in the same row differ significantly (P<0.05).
TABLE 5. EFFECT OF SEX AND CHILL TREATMENTS ON THE SENSORY EVALUATION OF BEEF LOIN STEAKS

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>DC</th>
<th>CC</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness - 1st</td>
<td>4.4**</td>
<td>5.4**</td>
<td>.16</td>
<td>4.70*</td>
<td>5.1*</td>
<td>.14</td>
</tr>
<tr>
<td>impression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tenderness-overall</td>
<td>4.8**</td>
<td>5.6**</td>
<td>.16</td>
<td>5.0*</td>
<td>5.4*</td>
<td>.13</td>
</tr>
<tr>
<td>Connective-tissue</td>
<td>4.2**</td>
<td>5.7**</td>
<td>.14</td>
<td>4.9</td>
<td>5.0</td>
<td>.13</td>
</tr>
<tr>
<td>residue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavor</td>
<td>4.9**</td>
<td>5.7**</td>
<td>.14</td>
<td>5.3</td>
<td>5.3</td>
<td>.13</td>
</tr>
<tr>
<td>Juiciness</td>
<td>4.4**</td>
<td>5.5**</td>
<td>.19</td>
<td>4.8</td>
<td>5.1</td>
<td>.13</td>
</tr>
</tbody>
</table>

*a* 8-point scale: 8=extremely tender, intense flavor, juicy or no connective tissue residue, 1=extremely tough, bland, dry or abundant connective tissue residue.

*b* DC: Delayed Chill.

*c* CC: Conventional Chill.

* Means with like superscripts within the same row differ significantly (P<0.05).

** Means with like superscripts within the same row differ significantly (P<0.01).
LITERATURE CITED


THE EFFECTS OF SEX AND DELAYED CHILL ON THE BIOPHYSICAL AND ORGANOLEPTIC PROPERTIES OF CHUNKED AND FORMED BEEF STEAK.

B.C. PATERSOHN, K.W. JONES, D.H. GEE AND

W.J. COSTELLO, SOUTH DAKOTA STATE UNIVERSITY, BROOKINGS.
ABSTRACT

South Devon cattle (10 bulls, 10 steers) were slaughtered to determine the effects of sex and postmortem temperature conditioning on the physiochemical and organoleptic properties of chunked and formed steak. The chuck from each left side was boned following a 4 h delayed chill (DC, 12.8 °C) treatment, mechanically tenderized and formulated into restructured (RS) steak products. Chucks from the right sides were boned following a 48 h conventional chill (CC, 2 °C) period and otherwise treated identical to the left sides. Bulls produced RS steaks less prone to oxidative rancidity. RS steaks from bulls exhibited higher (P<0.01) cooking losses and Kramer shear values. RS steaks from steers possessed more (P<0.05) desirable objective color scores. DC steaks had higher (P<0.01) color scores and higher (P<0.05) shear values than CC steaks. Trained sensory panelists determined that DC steaks had lower bind values (P<0.05); however, panelists found no differences in tenderness, juiciness, flavor and connective tissue residue for sex or chill treatment. There appears to be little difference due to sex or chill treatment in formulating satisfactory chunked and formed steak product.
INTRODUCTION

An increasing demand for animal protein by a growing world population makes it imperative that beef production efficiency increase. Presently, the intact male may offer potential for improving production efficiencies. Research indicates (Seideman et al., 1982a) that bulls utilize feed more efficiently, grow faster and produce a leaner carcass with more retail product than steers. However, 70 percent of the bull carcass may consist of cuts that are less tender and contain considerable amounts of connective tissue. Increasing the value of these lower quality cuts, has economically pressured the meat industry to develop the technology of restructured meat products. Restructured processing offers other advantages such as: (1) a controlled portion size; (2) a boneless product; (3) control of fat content; (4) convenience and (5) intermediate value (Ferren, 1972; Mandigo, 1974 and Breidenstein, 1982).

Chunking raw meat materials to form a restructured product works well in the restructuring process (Huffman and Cordray, 1979). The primary advantage of this process is that the final restructured steak product has visual and palatability attributes more nearly resembling intact steaks than restructured steaks made with flake-cut particles (Huffman, 1982). Cross and Allen (1982) state that bull meat has
low consumer acceptance because cooked meat from young bulls is often less tender than steer beef. Restructuring, via the chunking process, offers an opportunity to increase the tenderness of bull meat, while still presenting the consumer an intermediate cost product, with a steak-like texture.

The maximum utilization of carcasses and conservation of available energy is essential to help minimize the costs to the consumer (Huffman et al., 1984). The present system of chilling, reheating and rechillling tons of product each day has led to the concept of hot processing (Henrickson, 1982). Hot processing is the removal of bone and trim prior to chilling the edible portion of the carcass. Henrickson (1975) states that total energy savings could be 50% or more when hot processing is compared to the present processing scheme. Solomon and Schmidt (1980) reported that hot processing muscle may offer protein functionality advantages to the restructuring process. However, the use of hot processed, prerigor muscle for restructured steaks may also have some disadvantages. The principal disadvantage may be a decrease in tenderness due to cold shortening or thaw rigor. However, conditioning sides at near physiological temperatures for a period of 3-6 h postmortem may alleviate tenderness problems associated with hot processed muscle (Henrickson et al., 1974; Falk et al., 1975).
The combination of restructuring and hot processing, in conjunction with carcass conditioning, may offer an excellent process for improving the less palatable cuts from bull carcasses. The purpose of this study was to identify differences due to sex in the quality of chunked and formed beef steaks and to incorporate hot processing and high temperature conditioning into the processing scheme.
EXPERIMENTAL PROCEDURE

STEAK PREPARATION

The restructuring process employed in this study is presented in figure 1. South Devon steers (n=10) and bulls (n=10) were slaughtered at 16 mo of age and the chucks from the left sides were boned following a 4 h delayed chill treatment (12.8 °C) while chucks from the right sides were boned following a 48 h conventional chill (2 °C) period. Boned and trimmed chucks were needle tenderized (Ross TC 700, Ross Industries, Midland, Virginia; 2.54 cm advance setting) three times to assure connective tissue breakdown, then ground through a 2.54 cm plate (Hobart Mixer-Grinder; Hobart Manufacturing Co., Troy, Ohio). The fat source (chuck and plate) was fine flaked (Urschel 3600 Comitrol, 120 head; Urschel Laboratories, Valparaiso, Indiana) at a temperature of -5 °C prior to mixing. Fat and salt (0.5%) were added during the first 30 sec of blending and batches were mixed in a double-ribbon blender (Leland Food Mixer 100 DA; Leland Detroit Manufacturing Co., Detroit, Michigan) for 10 min. Each chuck was used to prepare a 9.1 kg batch formulated to an approximated 15% fat content. Lean tissue was estimated to contain 6-9% fat, thus 10% fat (by weight) was added to the lean in order to approximate a 15% fat content. Three, 1 kg samples, were removed from each batch, hand-formed in
Cryo-Vac bags and vacuum packaged. The logs were blast chilled in a -30 C freezer to -3 C, internal temperature, then tempered at -3 C for 12 h. Frozen logs were pressed at 1.72 MPA (250 lb/in²) using a cylindrical tube (62 cm²) and a Carver laboratory press. Pressed logs were cleaved (Hobart Commercial Slicer 1712; Hobart Manufacturing Co., Troy, Ohio) into 2.54 cm thick steaks, vacuum packaged and frozen at -25 C for later analyses.

CHEMICAL ANALYSIS

Proximate composition for fat, moisture, protein and ash was determined on duplicate samples using a modification of AOAC (1975) standard procedures. One sample was used to determine moisture (oven drying, AOAC 1975), fat (soxhlet extraction, AOAC 1975) and protein (Kjeldahl, AOAC 1975). A separate sample was used to determine percent ash (AOAC 1975). Thiobarbituric acid (TBA) values were determined in duplicate using the procedure of Tarladgis et al. (1960) after one wk and 90 d of frozen storage (-25 C).

COOKING PROCEDURE

All steaks used for sensory evaluation, cook loss determination and Lee-Kramer analysis were cooked at 177 C to an internal temperature of 70 C in a convection oven (Toastmaster). Internal temperature was measured by copper-constantan thermocouples inserted into the center of the steaks. Steaks were blotted dry and cook losses were determined 1 h
after cooking. Total cook loss was partitioned into evapora-
tive and drip losses.

Following cook loss determinations, steaks were used
for Lee-Kramer shear tests. Sensory evaluation samples were
held at a constant 50 C using a double boiler system as
described by Caporaso (1978).

LEE-KRAMER

Steaks were trimmed to a 45 x 45 mm size and weighed.
The Lee-Kramer shear press (Model SP-11) was equipped with a
1365 kg manual dial proving ring with a 20 sec cell speed.
Shear force was determined by dividing the peak force by the
sample weight and multiplying by 10 (kg force/10 g sample).

COLOR ANALYSIS

Fabricated steaks were evaluated with a Bausch-Lomb
Spectronic 20 equipped with the Color Analyzer Reflectance
Attachment. Each replicate of each treatment was measured
four times (2 readings for each of 2 steaks). The reflect-
ance attachment measured a rectangular 2 x 8 mm area on the
meat surface. Major fat areas were avoided. A magnesium
block was used for 100% reflectance. Objective color mea-
surements were determined using % reflectance at 630 nm minus
% reflectance at 580 nm (van den Oord and Wesdorp, 1971).
Reflectance at 630 nm is high for oxymyoglobin and low for
metmyoglobin. The reverse is true at 580 nm. Therefore, a
higher value indicates a brighter red color.
SENSORY EVALUATION

Panelist selection was based upon interest, availability and consistency of evaluation during ten training sessions. During training, score sheets and instructions were outlined. A variety of intact or restructured muscle tissues, cooking times and temperatures were used to provide examples over the entire scale of characteristics judged. Group discussions were held after each training session to refine sensory impressions of the panelists. Eight individuals were selected to participate on the panel. Panelists were served in individual booths under red lights. Three sessions were held each week with five samples being evaluated at each session. Each sample was evaluated using an 8-point scale. An 8 was extremely tender, juicy, intense flavor, extreme bind or no connective tissue residue and 1 was extremely tough, dry, bland, no bind or abundant in connective tissue residue. Sensory evaluations were conducted within a 90 d period from steak formulation.

STATISTICAL ANALYSES

Analysis of variance was determined using a 2 sex by 2 chill treatment factorial arrangement of treatments in a split-plot design as described by Steel and Torrie (1980) with sex as the main effect and chill treatments as the subplots. Ten replications were used with replications being represented by individual animals.
RESULTS AND DISCUSSION

The chemical composition of the chunked and formed steaks is presented in table 1. Restructured steaks from steers contained lower (P<0.01) amounts of moisture than steaks from bulls. DC steaks from steers possessed lower (P<0.01) moisture percentages than CC steaks from steers (figure 2); however, DC and CC restructured steaks from bulls had similar values.

Chunked and formed steaks from bulls possessed a lower (P<0.01) fat content than steaks from steers (table 1). CC steaks from steers exhibited lower (P<0.01) fat percentages than DC steaks from steers (figure 3); however, DC and CC restructured steaks from bulls had equal values.

Percent fat differences of restructured steaks can be partially explained by the fact that the bulls were leaner than steers (Paterson, 1984); however, formulation error is probably the major cause contributing to the proximate analysis differences in fat and moisture. Booren et al. (1981a) reported that higher amounts of inter- and intramuscular fat in the chuck as compared to the round made it more difficult to formulate steaks to a constant fat level when using chucks. Similar difficulties in estimating fat content of bull and steer chucks probably led to the percentage fat difference in this study. This fat content difference would affect percentage moisture creating the interactions present.
Chill treatments did not affect percent protein, but restructured steaks produced from intact males possessed significantly (P<0.01) higher protein percentages than steaks produced from castrated males. Lean tissue from bulls has been shown to contain higher percentages of protein than that of steers. (Jacobs et al., 1977). Percentage ash was not affected by sex or chill treatments.

TBA values are reported in table 2. Differences in initial TBA values of steaks produced from bulls or steers were not significant (P>0.05). DC steaks had significantly (P<0.01) lower initial TBA values than CC steaks. It should be noted that DC chucks were held for a shorter time postmortem prior to processing which could have created the difference in TBA values. This would agree with previous research (Booren et al., 1981a) who reported that lower TBA values in sectioned and formed beef steaks could be explained by shorter postmortem storage times prior to processing.

Restructured steaks from bulls possessed significantly (P<0.01) lower 90 d TBA values for both chill treatments than restructured steaks from steers. This difference could be due to a lower fat content in the restructured steaks from bulls (table 1). DC restructured steaks exhibited lower (P<0.01) 90 d TBA values than CC steaks. The difference in the 90 d TBA values is similar to that present at one week. This indicates that fat oxidation proceeded at
a similar rate for both chill treatments following the initial difference detected at one week.

Tenderness as measured by the Kramer shear cell is reported in table 2. Chunked and formed steaks produced from bulls were significantly (P<0.01) less tender than steaks produced from steers; however, this significant tenderness difference was not expressed by trained sensory panelists (table 3). Paterson (1984) reported that bulls tended to be less tender than steers as measured by Warner-Bratzler shear tests. This inherent tenderness difference may have caused the tenderness differences detected by the Kramer shear analyses in this study. Perhaps Kramer shear tests and sensory panelists measure different components of tenderness in restructured steaks.

DC restructured steaks were significantly (P<0.05) less tender than CC steaks as indicated by higher peak shear force values. However, sensory panelists did not detect significant tenderness differences between DC and CC chunked and formed steaks (table 3).

Chunked and formed steaks from bulls exhibited greater (P<0.01) total cook losses (table 2). However, sex had no effect when cook losses were partitioned into evaporative and drip loss fractions.

Water is a principal constituent of lean meat and is inversely related to the fat content in a product. Due to the evaporation rate of water and the melting point of fat, a
high lean to fat ratio would allow greater losses of water in a product due to cooking (Levick, 1978). This theory coincides with the proximate analysis data (table 1) as restructured steaks from bulls possessed a higher lean to fat ratio than restructured steaks from steers. Chill treatment did not affect total cook loss nor evaporative loss, but DC steaks had higher ($P < 0.05$) drip losses than CC steaks.

Surface color of chunked and formed beef steaks was objectively measured using $\%R_{630} - \%R_{580}$ (van den Oord and Wesdorp, 1971). Using data collected from another experiment using these same cattle, Paterson (1984) reported that bulls tended to possess darker 12th rib lean color scores than steers. This difference in lean color may have attributed to the significantly ($P < 0.05$) lower (darker) objective color values received by the restructured steaks from bulls as compared to the restructured steaks from steers (table 2).

DC steaks received significantly ($P < 0.01$) higher (brighter) objective color values than CC steaks. Chucks were boned 4 h postmortem and aerobically stored prior to processing into DC chunked and formed steaks. This processing step may have created the more desirable color exhibited by the DC steaks. Previous research (Judge and Aberle, 1980) has shown that metmyoglobin formation in prerigor muscle can be reduced by aerobic storage.
Trained sensory panel analysis results (table 3) indicated that sex had no affect on any of the sensory characteristics tested. CC steaks received higher (P<0.05) bind values indicating a more cohesive product than DC steaks. Chill treatment had no other effect on the sensory qualities of the restructured steaks. TBA values (table 2) indicated that lipid oxidation had occurred to a significant extent by d 90 but apparently not sufficient for detection by the sensory panel. These sensory panel results differ with those of Seideman et al. (1982b) who reported that hot-boned beef resulted in less tender restructured steaks that possessed less desirable flavor than steaks made from beef aged 48 h. However, steaks produced by Seideman et al. (1982b) were sliced and formed restructured steaks and a conditioning period was not included in the processing scheme.

Field (1982) stated that connective tissue is the largest single problem in restructured chunked and formed steaks. Sensory panel scores for connective tissue residue were acceptable (6.0 or higher) for the chunked and formed steaks in this study. It appears the processing scheme used in the steak formulation (figure 1) eliminated the problems associated with connective tissue.
CONCLUSION

In summary, these data demonstrate that chucks from young bulls can be used as a raw material for producing satisfactory chunked and formed steaks. In addition, hot boning used in conjunction with a carcass conditioning period can be successfully incorporated into the processing scheme of chunked and formed beef steaks. Additional research is needed to further examine the affects of hot boning and carcass conditioning on the biophysical and sensory properties of restructured steaks.
Figure 1. PROCESSING SCHEME FOR BEEF CHUNKED AND FORMED STEAKS.
TABLE 1. EFFECT OF SEX AND CHILL TREATMENT ON THE CHEMICAL COMPOSITION OF CHUNKED AND FORMED BEEF STEAKS

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>DC</th>
<th>CC</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, % +</td>
<td>70.99**</td>
<td>68.95**</td>
<td>.41</td>
<td>69.58**</td>
<td>70.36**</td>
<td>.10</td>
</tr>
<tr>
<td>Fat, % +</td>
<td>10.26**</td>
<td>13.07**</td>
<td>.53</td>
<td>12.11**</td>
<td>11.23**</td>
<td>.08</td>
</tr>
<tr>
<td>Protein, %</td>
<td>17.91**</td>
<td>17.17**</td>
<td>.18</td>
<td>17.55</td>
<td>17.54</td>
<td>.03</td>
</tr>
<tr>
<td>Ash, %</td>
<td>1.30</td>
<td>1.28</td>
<td>.02</td>
<td>1.29</td>
<td>1.29</td>
<td>.01</td>
</tr>
</tbody>
</table>

**Means with like superscripts in the same row differ significantly (P<0.01).

+Chill x sex interaction, significant (P<0.05), see figures 2 and 3.

a  DC: Delayed Chill.

b  CC: Conventional Chill.
## TABLE 2. EFFECT OF SEX AND CHILL TREATMENT ON TBA VALUES, KRAMER SHEAR, COOK LOSSES AND OBJECTIVE COLOR VALUES

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>a</th>
<th>b</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBA Value 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 Time</td>
<td>.56</td>
<td>.63</td>
<td>.04</td>
<td>.53</td>
<td>.66</td>
<td>.01</td>
</tr>
<tr>
<td>90 days</td>
<td>1.38**</td>
<td>1.61**</td>
<td>.06</td>
<td>1.42**</td>
<td>1.57**</td>
<td>.02</td>
</tr>
<tr>
<td>Kramer peak 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>force</td>
<td>6.35**</td>
<td>5.64**</td>
<td>.12</td>
<td>6.12*</td>
<td>5.88*</td>
<td>.08</td>
</tr>
<tr>
<td>Total cook loss, %</td>
<td>32.87**</td>
<td>30.05**</td>
<td>.59</td>
<td>31.53</td>
<td>31.39</td>
<td>.67</td>
</tr>
<tr>
<td>Evaporative loss, %</td>
<td>20.25</td>
<td>19.48</td>
<td>.71</td>
<td>18.99</td>
<td>20.74</td>
<td>.90</td>
</tr>
<tr>
<td>Drip loss, %</td>
<td>12.62</td>
<td>10.57</td>
<td>.62</td>
<td>12.54*</td>
<td>10.65*</td>
<td>.62</td>
</tr>
<tr>
<td>%R630-%R580</td>
<td>.14*</td>
<td>.17*</td>
<td>.009</td>
<td>.19**</td>
<td>.12**</td>
<td>.007</td>
</tr>
</tbody>
</table>

1 mg malonaldehyde/kg meat.

2 kg force/10 g sample.

* Means with like superscripts in the same row differ significantly (P<0.05).

** Means with like superscripts in the same row differ significantly (P<0.01).

a DC: Delayed Chill.

b CC: Conventional Chill.
### TABLE 3. EFFECT OF SEX AND CHILL TREATMENT ON SENSORY EVALUATION OF CHUNKED AND FORMED STEAKS

<table>
<thead>
<tr>
<th></th>
<th>Bulls</th>
<th>Steers</th>
<th>SE</th>
<th>DC</th>
<th>CC</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenderness</td>
<td>6.2</td>
<td>6.3</td>
<td>.09</td>
<td>6.2</td>
<td>6.3</td>
<td>.07</td>
</tr>
<tr>
<td>Flavor</td>
<td>6.3</td>
<td>6.1</td>
<td>.09</td>
<td>6.1</td>
<td>6.3</td>
<td>.07</td>
</tr>
<tr>
<td>Juiciness</td>
<td>6.2</td>
<td>6.3</td>
<td>.16</td>
<td>6.2</td>
<td>6.3</td>
<td>.07</td>
</tr>
<tr>
<td>Bind</td>
<td>4.2</td>
<td>4.1</td>
<td>.12</td>
<td>4.0*</td>
<td>4.3*</td>
<td>.09</td>
</tr>
<tr>
<td>Connective tissue residue</td>
<td>6.0</td>
<td>6.2</td>
<td>.16</td>
<td>6.0</td>
<td>6.2</td>
<td>.08</td>
</tr>
</tbody>
</table>

a One to eight scale with eight being extremely tender, juicy, intense flavor, extreme bind or no connective tissue residue and one being extremely tough, dry, bland, no bind or abundant connective tissue residue.

* Means with like superscripts within the same row differ significantly (P<0.05).

b DC: Delayed Chill.

c CC: Conventional Chill.
BULLS

71.1 ± .31

70.9 ± .32

STEERS

69.6 ± .36

68.3 ± .26

% Moisture

DC

CC

Chill Treatment

FIGURE 2. SEX X CHILL INTERACTION
FOR PERCENT MOISTURE.
FIGURE 3. SEX X CHILL INTERACTION FOR PERCENT FAT.
LITERATURE CITED

AOAC. 1975. Official Methods of Analysis (12th Ed.)
Association of Official Agricultural Chemists.
Washington, DC.

Booren, A.M., Mandigo, R.W., Olson, D.G. and Jones, K.W.
1981a. Effect of muscle type and mixing time on
sectioned and formed beef steaks. J. Food Sci.
46:1665.

Booren, A.M., Mandigo, R.W., Olson, D.G. and Jones, K.W.
1981b. Vacuum mixing influence on characteristics
of sectioned and formed beef steaks. J. Food Sci.
46:1673.

Breidenstein, B.C. 1982. Intermediate value beef products
(Restructured beef products). National Livestock
and Meat Board. Chicago, IL.

intact males--slaughter to retail. Presented to
the Midwestern Section of the Amer. Soc. of Anim.

Effect of boning beef carcasses prior to chilling

Ferren, R. 1972. Flake-cutting. A guide to determine the
formulation for the type of meat and poultry pro-
ducts you want. Bull. 691. Urschel Laboratories
Inc., Valparasio, IN.

Field, R.A. 1982. New restructured meat products--food


In "Proc. International Symposium Meat Science and
Technology." p 169.

quality resulting from muscle boning the unchilled
and Technol. IV:124.


PROCEDURE 1

R-VALUE DETERMINATION


I. Reagents:

A. 0.9 M perchloric acid
   74.7 ml 70-72% perchloric acid / L of solution

B. 2.0 M potassium hydroxide
   112.22 g / L of solution

C. 0.1 M potassium phosphate buffer (pH 6.5)
   0.1 M monobasic = 13.61 g / L
   0.1 M dibasic = 17.42 g / L
   Monobasic:dibasic = 1.75:1.0

II. Procedure: (conduct in duplicate)

1. Weigh 4 g of powdered meat sample into a 250 ml blender jar.

2. Add 40 ml of 0.9 M perchloric acid.

3. Homogenize 1 min.

4. Transfer to 50 ml centrifuge tube and cap.

5. Centrifuge at 3000 x G for 10 min.

6. Filter supernatant through Whatman no. 1 filter paper into 100 ml beaker.
7. Adjust pH to 6.0 to 6.5 with 2.0 M potassium hydroxide (takes approx. 15 ml, use a buret).

8. Chill in ice bath at least 30 min.

9. Filter small portion through Whatman no. 1 filter paper.

10. Add 0.3 ml of extract to 8.7 ml of potassium phosphate buffer.

11. Vortex solution thoroughly.

12. Zero spectrophotometer to buffer.

13. Record absorbance at 250 and 260 nm. Rezeroing the spectrophotometer when changing wavelength.

PROCEDURE 2

TBA DETERMINATION


I. Reagents:

A. TBA Reagent. 0.02 M 2-thiobarbituric acid in 90% glacial acetic acid. Bring into solution by warming slightly in a boiling water bath. Solution must be perfectly clear.

B. HCL Solution. 1 part concentrated HCL to 11 parts water (approx. 1N).

II. Procedure: (conduct in duplicate)

1. Blend 10 g meat with 50 ml distilled water in blender for 2 min.

2. Transfer quantitatively to Kjeldahl flask by washing with two 25 ml aliquots of 1.0 N HCL.

3. Spray a small amount of Dow Artifoam A into lower neck of the flask. Add a few saddle stones to prevent bumping.

4. Assemble apparatus on Kjeldahl distillation apparatus.

5. Distill at highest obtainable temperature.

6. Collect 50 ml distillate.

7. Mix distillate, pipette 5 ml into 50 ml glass-stoppered tube, add 5 ml of TBA.

8. Stopper tubes, vortex contents, immerse in boiling water bath for 35 min.

9. Use a distilled water + TBA blank and treat like samples.
10. After heating, cool in tap water for 10 min, transfer to cuvette, read O.D. against blank at 538 nm.

11. Multiply reading by factor 7.8 to convert to mg of malonaldehyde per 1000 g of meat.
PROCEDURE 3

COOK LOSS DETERMINATIONS

Raw steak weight = (pan wt + raw steak wt) - pan wt

Cooked steak wt = actual wt from blotted, cooled steaks

Percent total loss = raw steak wt - cooked steak wt
                   raw steak wt

Total loss = raw steak wt - cooked steak wt

Percent evaporative loss =
pan + raw steak wt - pan + cooked steak wt x % total loss
                             total loss (g)

Percent drip loss = % total loss - % evaporative loss
PROCEDURE 4

SARCOMERE LENGTH DETERMINATIONS


Procedure:
1. Muscle fiber bundles are fixed in 2% glutar-aldehyde.
2. Rinse in .2 M phosphate buffer (2-10 min washings).
3. Tease fibers from bundles.
4. Mount 10 fibers on glass slides with a drop of buffer. Place cover slip over top of sample and blot fluid from around the edges of the slip.
5. Mount slide onto a holding device on the optical bench so that the fiber lay in the path of the laser.
6. Place the screen 100 mm from the sample.
7. Record the distance between 0th and 1st order diffraction bands.
8. Convert to sarcomere length using the formula.

\[ d = \frac{(632.8 \times 10^{-4} \text{ um}) \times (D)}{S} \]

\[ d = \text{sarcomere length} \]
\[ D = \text{Distance from the muscle fiber to the screen on which the diffraction bands are formed.} \]
\[ S = \text{Distance (mm) between the zeroth and first order diffraction bands.} \]
FIGURE 1
PALATABILITY SCORE SHEET
For Trained Descriptive Attribute Panel

<table>
<thead>
<tr>
<th>Tenderness (First Impression)</th>
<th>Tenderness (Overall Impression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extremely tender</td>
<td>8 Extremely tender</td>
</tr>
<tr>
<td>7 Very tender</td>
<td>7 Very tender</td>
</tr>
<tr>
<td>6 Moderately tender</td>
<td>6 Moderately tender</td>
</tr>
<tr>
<td>5 Slightly tender</td>
<td>5 Slightly tender</td>
</tr>
<tr>
<td>4 Slightly tough</td>
<td>4 Slightly tough</td>
</tr>
<tr>
<td>3 Moderately tough</td>
<td>3 Moderately tough</td>
</tr>
<tr>
<td>2 Very tough</td>
<td>2 Very tough</td>
</tr>
<tr>
<td>1 Extremely tough</td>
<td>1 Extremely tough</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Flavor (Intensity)</th>
<th>Juiciness</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extremely intense</td>
<td>8 Extremely juicy</td>
</tr>
<tr>
<td>7 Very intense</td>
<td>7 Very juicy</td>
</tr>
<tr>
<td>6 Moderately intense</td>
<td>6 Moderately juicy</td>
</tr>
<tr>
<td>5 Slightly intense</td>
<td>5 Slightly juicy</td>
</tr>
<tr>
<td>4 Slightly bland</td>
<td>4 Slightly dry</td>
</tr>
<tr>
<td>3 Moderately bland</td>
<td>3 Moderately dry</td>
</tr>
<tr>
<td>2 Very bland</td>
<td>2 Very dry</td>
</tr>
<tr>
<td>1 Extremely bland</td>
<td>1 Extremely dry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connective Tissue</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8 None</td>
<td></td>
</tr>
<tr>
<td>7 Practically none</td>
<td></td>
</tr>
<tr>
<td>6 Traces</td>
<td></td>
</tr>
<tr>
<td>5 Slight</td>
<td></td>
</tr>
<tr>
<td>4 Moderate</td>
<td></td>
</tr>
<tr>
<td>3 Slightly abundant</td>
<td></td>
</tr>
<tr>
<td>2 Moderately abundant</td>
<td></td>
</tr>
<tr>
<td>1 Abundant</td>
<td></td>
</tr>
</tbody>
</table>
### FIGURE 2

**PALATABILITY SCORE SHEET**

<table>
<thead>
<tr>
<th>Tenderness</th>
<th>Flavor Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extremely tender</td>
<td>8 Extremely intense</td>
</tr>
<tr>
<td>7 Very tender</td>
<td>7 Very intense</td>
</tr>
<tr>
<td>6 Moderately tender</td>
<td>6 Moderately intense</td>
</tr>
<tr>
<td>5 Slightly tender</td>
<td>5 Slightly intense</td>
</tr>
<tr>
<td>4 Slightly tough</td>
<td>4 Slightly bland</td>
</tr>
<tr>
<td>3 Moderately tough</td>
<td>3 Moderately bland</td>
</tr>
<tr>
<td>2 Very tough</td>
<td>2 Very bland</td>
</tr>
<tr>
<td>1 Extremely tough</td>
<td>1 Extremely bland</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Juiciness</th>
<th>Connective Tissue</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extremely juicy</td>
<td>8 None</td>
</tr>
<tr>
<td>7 Very juicy</td>
<td>7 Practically none</td>
</tr>
<tr>
<td>6 Moderately juicy</td>
<td>6 Traces</td>
</tr>
<tr>
<td>5 Slightly juicy</td>
<td>5 Slight</td>
</tr>
<tr>
<td>4 Slightly dry</td>
<td>4 Moderate</td>
</tr>
<tr>
<td>3 Moderately dry</td>
<td>3 Slightly abundant</td>
</tr>
<tr>
<td>2 Very dry</td>
<td>2 Moderately abundant</td>
</tr>
<tr>
<td>1 Extremely dry</td>
<td>1 Abundant</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bind Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 Extreme bind</td>
</tr>
<tr>
<td>7 Very strong bind</td>
</tr>
<tr>
<td>6 Strong bind</td>
</tr>
<tr>
<td>5 Moderate bind</td>
</tr>
<tr>
<td>4 Slight bind</td>
</tr>
<tr>
<td>3 Very slight bind</td>
</tr>
<tr>
<td>2 Practically no bind</td>
</tr>
<tr>
<td>1 No bind</td>
</tr>
</tbody>
</table>
FIGURE 3

Test Parameters and Evaluation Methods

1. Tenderness (first impression)
   a. Place sample between back molars.
   b. Slowly chew 3 times (3 seconds between chews).
   c. Rank initial tenderness 1-8 based on degree of resistance of first 3 chews.

2. Tenderness (overall impression)
   a. Chew same test sample 7 more times (3 sec between chews).
   b. Place samples firmly between back molars.
   c. Use tongue to push/pull sample from between molars to center of mouth.
   d. Be conscious of degree of sample disintegration.
   e. Chew 10 more times (3 sec between chews).
   f. Repeat c. above.
   g. Record overall impression of tenderness.

3. Juiciness
   a. Evaluate juiciness during first 3 chews of sample.
   b. Be cautious not to let initial tenderness interfere.
   c. Be conscious of moisture exuding from sample.

4. Flavor Intensity
   a. Evaluate during first 10 chews.
   b. Evaluate intensity of flavor, not preference.

5. Connective Tissue Residue
   a. After 20 chews, place remaining sample mass in center of tongue.
   b. With tongue pressed firmly against roof of mouth, initiate strong sucking action (mouth closed; do not swallow).
   c. Connective tissue residue will hold in place and can be distinguished from other muscle components.

6. Bind
   a. Complete prior to chewing.
b. Place sample between back molars.
c. Pull/push on sample with tongue.
d. Evaluate for sample disintegration.
### TABLE 1. ANALYSIS OF VARIANCE FOR CARCASS TRAITS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Hot carcass wt</th>
<th>Fat thickness</th>
<th>Longissimus muscle area</th>
<th>Est. KPH fat</th>
<th>USDA yield grade</th>
<th>Marbling score</th>
<th>Longissimus firmness</th>
<th>Longissimus firmness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>3134.7*</td>
<td>.55**</td>
<td>976.51**</td>
<td>.61</td>
<td>3.83**</td>
<td>8405.0*</td>
<td>5.00**</td>
<td>1.25</td>
</tr>
<tr>
<td>Residual</td>
<td>19</td>
<td>772.78</td>
<td>.07</td>
<td>102.27</td>
<td>.20</td>
<td>.33</td>
<td>2231.7</td>
<td>.43</td>
<td>.76</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P<.05.)*  
**(P<.01.)*

### TABLE 2. ANALYSIS OF VARIANCE FOR LONGISSIMUS pH AND TEMPERATURE

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>pH 1 hr</th>
<th>pH 2 hr</th>
<th>pH 4 hr</th>
<th>pH 8 hr</th>
<th>pH 24 hr</th>
<th>Temp 1 hr</th>
<th>Temp 2 hr</th>
<th>Temp 4 hr</th>
<th>Temp 8 hr</th>
<th>Temp 24 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>.052</td>
<td>.400*</td>
<td>.300</td>
<td>.237</td>
<td>.110</td>
<td>.016</td>
<td>13.23**</td>
<td>39.01**</td>
<td>.625</td>
<td>.016</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>.101</td>
<td>.086</td>
<td>.120</td>
<td>.108</td>
<td>.072</td>
<td>.850</td>
<td>1.25</td>
<td>1.44</td>
<td>2.91</td>
<td>1.10</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>.005</td>
<td>.001</td>
<td>.043</td>
<td>.079</td>
<td>.002</td>
<td>.256</td>
<td>7.23**</td>
<td>79.81</td>
<td>2.03</td>
<td>58.08**</td>
</tr>
<tr>
<td>Residual</td>
<td>19</td>
<td>.013</td>
<td>.013</td>
<td>.012</td>
<td>.011</td>
<td>.014</td>
<td>.190</td>
<td>.501</td>
<td>1.21</td>
<td>1.04</td>
<td>.536</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>.013</td>
<td>.013</td>
<td>.012</td>
<td>.011</td>
<td>.014</td>
<td>.190</td>
<td>.501</td>
<td>1.21</td>
<td>1.04</td>
<td>.536</td>
</tr>
</tbody>
</table>

*(P<.05.)*  
**(P<.01.)*
<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>R-2 hr</th>
<th>R-4 hr</th>
<th>R-8 hr</th>
<th>R-24 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>.021</td>
<td>.017</td>
<td>.001</td>
<td>.004</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>.006</td>
<td>.005</td>
<td>.006</td>
<td>.007</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>.001</td>
<td>.004</td>
<td>.007</td>
<td>.002</td>
</tr>
<tr>
<td>Residual</td>
<td>59</td>
<td>.003</td>
<td>.004</td>
<td>.007</td>
<td>.009</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P < .05.)*
TABLE 4. ANALYSIS OF VARIANCE FOR SARCOMERE LENGTH AND COOK LOSS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean squares (Sarcomere length)</th>
<th>Mean squares (Cook loss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.119*</td>
<td>0.0061</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>0.016</td>
<td>0.0025</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>0.029</td>
<td>0.0136</td>
</tr>
<tr>
<td>Residual</td>
<td>18</td>
<td>0.012</td>
<td>0.0035</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P<.05.)*

TABLE 5. ANALYSIS OF VARIANCE FOR WARNER-BRATZLER SHEAR TESTS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Mean squares (Warner-Bratzler)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>7.69</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>17.29</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>13.88*</td>
</tr>
<tr>
<td>Residual</td>
<td>252</td>
<td>3.44</td>
</tr>
<tr>
<td>Total</td>
<td>272</td>
<td></td>
</tr>
</tbody>
</table>

*(P<.05.)*
### TABLE 6. ANALYSIS OF VARIANCE FOR SENSORY EVALUATIONS OF INTACT STEAKS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Tenderness 1st impression</th>
<th>Tenderness overall</th>
<th>Flavor</th>
<th>Juiciness</th>
<th>Connective tissue residue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>68.33**</td>
<td>49.58**</td>
<td>37.01**</td>
<td>83.70**</td>
<td>130.87**</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>3.91</td>
<td>4.15</td>
<td>3.30</td>
<td>5.52</td>
<td>3.19</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>10.59*</td>
<td>14.43*</td>
<td>.31</td>
<td>3.19</td>
<td>2.34</td>
</tr>
<tr>
<td>Panel</td>
<td>7</td>
<td>15.27</td>
<td>8.05</td>
<td>9.04</td>
<td>15.13</td>
<td>24.93</td>
</tr>
<tr>
<td>Residual</td>
<td>265</td>
<td>2.95</td>
<td>2.80</td>
<td>2.52</td>
<td>2.72</td>
<td>2.82</td>
</tr>
<tr>
<td>Total</td>
<td>272</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P<.05.)*

**(P<.01.)*
# TABLE 7. ANALYSIS OF VARIANCE FOR TBA, LEE-KRAMER AND PROXIMATE COMPOSITION

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>TBA 1 week</th>
<th>TBA 90d</th>
<th>Lee-Kramer</th>
<th>Moisture</th>
<th>% Fat</th>
<th>% Protein</th>
<th>% Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>.102</td>
<td>1.10**</td>
<td>49.06**</td>
<td>82.89**</td>
<td>157.70**</td>
<td>11.01**</td>
<td>.009</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>.048</td>
<td>.150</td>
<td>2.80</td>
<td>6.72</td>
<td>11.29</td>
<td>.028</td>
<td>.009</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>.367**</td>
<td>.260**</td>
<td>5.82*</td>
<td>12.05**</td>
<td>15.54**</td>
<td>.002</td>
<td>.001</td>
</tr>
<tr>
<td>S x T</td>
<td>1</td>
<td>.004</td>
<td>.250</td>
<td>.400</td>
<td>5.76</td>
<td>15.35</td>
<td>2.66</td>
<td>.003</td>
</tr>
<tr>
<td>R x T (Sex)</td>
<td>18</td>
<td>.025</td>
<td>.070</td>
<td>4.21</td>
<td>.940</td>
<td>2.38</td>
<td>1.07</td>
<td>.009</td>
</tr>
<tr>
<td>Residual</td>
<td>40</td>
<td>.003</td>
<td>.010</td>
<td>1.29</td>
<td>.360</td>
<td>.242</td>
<td>.260</td>
<td>.004</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P< .05.)*

**(P< .01.)*
### TABLE 8. ANALYSIS OF VARIANCE FOR COOK LOSS IN RESTRUCTURED STEAKS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Total loss</th>
<th>Evaporative loss</th>
<th>Drip loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>79.52**</td>
<td>5.85</td>
<td>44.31</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>6.95</td>
<td>10.12</td>
<td>12.24</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>.196</td>
<td>30.45</td>
<td>33.67*</td>
</tr>
<tr>
<td>Residual</td>
<td>19</td>
<td>8.59</td>
<td>12.35</td>
<td>7.52</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P<.05.)*

**(P<.01.)*
### TABLE 9. ANALYSIS OF VARIANCE FOR OBJECTIVE COLOR VALUES

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>66.63*</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>15.14**</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>471.79**</td>
</tr>
<tr>
<td>Residual</td>
<td>59</td>
<td>9.30</td>
</tr>
<tr>
<td>Total</td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>

*(P < .05.)*  
**(P < .01.)*

### TABLE 10. ANALYSIS OF VARIANCE FOR SENSORY EVALUATION OF RESTRUCTURED STEAKS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Tender-ness</th>
<th>Flavor</th>
<th>Juiciness</th>
<th>Connective tissue residue</th>
<th>Bind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>4.05</td>
<td>2.63</td>
<td>1.01</td>
<td>1.80</td>
<td>3.00</td>
</tr>
<tr>
<td>Rep (Sex)</td>
<td>18</td>
<td>3.01</td>
<td>1.30</td>
<td>4.01</td>
<td>4.11</td>
<td>2.40</td>
</tr>
<tr>
<td>Temp</td>
<td>1</td>
<td>.61</td>
<td>2.63</td>
<td>.61</td>
<td>2.45</td>
<td>5.78*</td>
</tr>
<tr>
<td>Panel</td>
<td>7</td>
<td>12.54</td>
<td>5.07</td>
<td>6.94</td>
<td>16.35</td>
<td>56.20</td>
</tr>
<tr>
<td>Residual</td>
<td>292</td>
<td>.78</td>
<td>.86</td>
<td>.80</td>
<td>.99</td>
<td>1.19</td>
</tr>
<tr>
<td>Total</td>
<td>319</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*(P < .05.)*