EFFECT OF SELECTED TIMES AND TEMPERATURES DURING HOLDING ON THE QUALITY CHARACTERISTICS AND THIAMINE CONTENT OF ROAST BEEF

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY
MARY ANN BOYLE
1968

THESIS

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ABSTRACT

EFFECT OF SELECTED TIMES AND TEMPERATURES DURING HOLDING ON THE QUALITY CHARACTERISTICS AND THIAMINE CONTENT OF ROAST BEEF

by Mary Ann Boyle

This study compared selected times and temperatures of holding and/or reheating on the palatability characteristics, weight losses and thiamine content of U. S. Choice grade beef loins. Heat transfer during cooking and holding were also examined.

All roasts were cooked in a 149°C. oven to an internal temperature of 54°C. as recorded by a potentiometer lead positioned in the center of the meat. After removal from the oven, roasts stood undisturbed at room temperature for 30 min.

Roasts serving as the control were sliced and served immediately. For holding methods one and two, roasts were held unsliced and sliced, respectively, over dry heat for 90 min. For the third method, roasts were refrigerated for approximately 24 hr. and then sliced and reheated to an internal temperature of 60°C.

An average of 93 min. was needed to cook the roasts to the rare stage of doneness. The average maximum temperature rise observed during the 30-min. standing period was 60°C.

During the 90 min. holding period, the temperature of roasts held unsliced rose from an initial temperature of 55.5°C. to an average of 58°C. while roasts held sliced rose to an average temperature of 59°C. from an initial temperature of 48.5°C. The refrigerated roasts had an average decline in temperature from 56.5°C. to 4.5°C. which required an average time of 7 hr. and 48 min. Except for a slight initial lag, a continuous rapid rate of temperature rise during the average 67.2 min. reheating period was noted.

Total, drip and volatile cooking losses did not differ significantly among treatments or animals. Total and drip holding losses were significantly higher ($P \leq 0.01$) for roasts held sliced than for roasts held unsliced which in turn were significantly higher ($P \leq 0.01$) than similar losses incurred during refrigerated holding. Volatile holding losses attributable to treatment were not significant. The accumulative total losses from roasts served immediately and roasts held unsliced were significantly lower ($P \leq 0.01$) than those from roasts held sliced which in turn were significantly lower ($P \leq 0.01$) than similar losses from roasts refrigerated and reheated. The weight of servable meat decreased in order for roasts served immediately, roasts held unsliced, roasts held sliced and roasts refrigerated and reheated.

Analyses of subjective evaluations showed roasts served immediately or held unsliced scored significantly higher

($P \leq 0.01$) for aroma quality, color of lean, flavor of fat, juiciness and tenderness than did roasts held sliced or refrigerated and reheated. Roasts served immediately and roasts held unsliced scored significantly higher ($P \leq 0.01$) in flavor of lean than roasts held sliced and these in turn were significantly higher ($P \leq 0.01$) than similar scores for roasts refrigerated and reheated. Roasts served immediately and roasts held unsliced were significantly juicier ($P \leq 0.01$) than roasts refrigerated and reheated as indicated by the percentage of press fluid. Kramer shear-press values expressed as maximum force and area-under-the-curve revealed no significant differences attributable to treatment or to animal.

The pH of the cooked samples varied significantly ($P \leq 0.05$) among treatments. Ranked in order of decreasing thiamine content, expressed on an as-determined basis, were the roasts held sliced, roasts refrigerated and reheated followed by roasts served immediately and roasts held unsliced with the same micrograms per gram of thiamine.

The results of this investigation indicate that roasts should be served immediately to insure maximum quality. However, if roasts must be held, they should be held unsliced to provide the most acceptable product.

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By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Institution Administration

1968

ACKNOWLEDGEMENTS

To Dr. Kaye Funk, the author wishes to express sincere and grateful appreciation for her guidance and unending patience during this investigation. Without her advice and invaluable assistance, this study would have been an impossible task.

Special thanks to Miss Katherine Hart for her interest in this study and kind advice during the two years of the author's graduate program. The author also wishes to thank Dr. Grace Miller and Miss Doris Downs for their interest and suggestions.

The author is also indebted to Mrs. Carol Weaver for the chemical analyses, to Mr. Jim Stiles for assistance in procuring the meat, to Dr. Frances Magrabi for help in the statistical analyses of the data and to Mrs. Mary Ellen Zabik for reading the manuscript.

Sincere appreciation is extended to Miss Gisele Charlebois, Sister Marcel DeJonckheere, Miss Doris M. Downs, Dr. Theodore F. Irmiter, Dr. Grace A. Miller, Miss Mary Morr and Sister Veronica Marie for their faithful participation on the taste panel.

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INTRODUCTION

In an effort for the food service industry to control operational costs, present trends are to shorten labor hours and utilize production facilities to the maximum. As a result, food products are often held for varying periods of time during different segments of the production and service cycle. Food prepared in hospitals may be held in food cabinets or in steam tables before and during tray assembly and distribution to patients. In volume feeding operations such as restaurants and cafeterias, cooked foods may be held under varying conditions prior to final preparation, such as slicing of meat, and/or service. Also, foods may be refrigerated after preparation and then reheated as needed for service. These holding and/or reheating conditions complicate the problem of insuring adequate time and temperature control over perishable foods.

Because of its nutritional and satiety value, meat constitutes a major portion of the American diet. The results of various cooking methods on physical and chemical properties of meat have been studied. However, limited data are available concerning the effect of various holding procedures on the quality characteristics and nutritive value of meat.

It was the purpose of this study to compare the effect of selected times and temperatures during holding and/or reheating on the palatability and thiamine content of short loins of beef. Losses due to drip and evaporation were also investigated.

Three methods for holding cooked meat were selected. For the first method, the meat was held unsliced for a period of 90 min. as would be done in a volume feeding operation when meats were roasted ahead of the scheduled serving period to free ovens for preparing last minute menu items or to have cooked meats available when needed for service to unpredicted numbers of people. Cooked meats held by the second method were sliced and held for 90 min. as would be done in a hospital with decentralized tray service and dormitories where large quantities of meat needed slicing for service during a relatively short period of time. For the first and second methods, the meat was held over dry heat with thermostats on the food warmers adjusted to maintain temperatures of 60 to 65°C. within the meat. For the third method, cooked and unsliced meat was refrigerated for approximately 24 hrs. before slicing and reheating to an internal temperature of 60°C. Roasts could be cooked and held in this manner to free ovens for other uses or to store the product when production has exceeded service requirements.

Data from subjective evaluations and objective measurements of the palatability characteristics and thiamine determinations will provide information for assessing the relative merits of the above holding and/or reheating conditions. From data showing losses due to drip and evaporation, indications of costs of weighed portions of roast beef can be obtained.

REVIEW OF LITERATURE

Methods of Meat Cookery

As early as 1898, researchers at the University of Illinois conducted experiments in methods to cook meat (24). Researchers at U. S. Agricultural Experiment Stations across the country have carried out research on meat cookery since the beginning of the twentieth century, and their work forms the basis of meat cooking methods used in volume feeding operations today (12,15,18,19,20,24).

Based on the results of seventeen years of research, the Committee on Preparation Factors of the Cooperative Meat Investigations published directions for planning and carrying out experiments on meat cookery (20). The committee summarized many studies to provide a means for testing the results of production and processing practices of various researchers.

Early experiments in meat cookery dealt with the effects of cooking time, temperature and method on cooking losses and quality characteristics of the product. Cline _et al_. cooked (19) beef rib roasts at constant oven temperatures of 110, 125, 163, 191, 218 and 260°C. to the rare stage of doneness. Their results showed total cooking losses increased as the oven temperature increased. Roasts cooked at 125 and 163°C. were judged more palatable, tender, and juicy than roasts cooked at other oven temperatures. These results are in agreement with another study reported by Cline, Loughead and Schwartz (18) in which total cooking losses also increased as cooking temperatures increased.

Conducting studies on the time and temperature necessary to cook the ideal rare, medium, and well done roasts, Latzke found (66) that standing rib roasts seared for 20 min. at 275°C. and then cooked at a constant oven temperature of 110 or 125°C. had greater uniformity of doneness than those cooked at 150 and 175°C. after searing. Internal temperatures of 51, 61, and 71°C. were established for rare, medium and well done roasts, respectively. She concluded it was advisable to sear roasts at 275°C. for 20 min. and then cook to an internal temperature of 61°C. at an oven temperature of 125°C. thus obtaining maximum flavor and color with the minimum amount of loss due to cooking. Using rib roasts, Alexander and Clark seared (3) the meat at 265°C. for 20 min. and then cooked it at 125°C. to an internal temperature of 56°C. When this method was compared with one in which roasts were cooked at a constant temperature of 150°C. to the same internal temperature, the data showed the searing method resulted in increased cooking losses. To study the effect of cooking method, Cline and Foster compared (17) constant oven temperatures of 100 and 225°C. with searing at 260°C. and then cooking at 125°C. Their results indicated cooking losses were lowest when a constant oven temperature of 100°C. was used; however, roasts prepared by the searing method had a preferred flavor.

Cover compared (21) the palatability of cuts of beef cooked in simmering water at 90°C. for 3 hr. with similar cuts roasted in a 90°C. oven for 23 hr. to the same internal temperature of 80°C. The presence of moisture around the meat did not increase the tenderness. Taste panelists preferred the oven cooked roasts. Bramblett and Vail wrapped (10) paired rounds of beef separately in aluminum foil and cooked one of each pair at oven temperatures of 69 and 93°C., respectively, to an internal temperature of 65°C. The percentage of cooking losses was less and palatability scores were higher for meat cooked at 93°C. than for meat cooked at 69°C.

In comparing the braising method of cooking with oven roasting at 121 and 149°C., Griswold found (48) cuts from rounds of beef more acceptable when roasted than when braised. Roasts cooked at 121°C. were judged superior to those cooked at 149°C. except for the dried surface appearance of meat cooked at the lower temperature. Hood roasted (58) cuts from rounds of beef in uncovered shallow pans at 149 and 177°C. and cooked similar cuts by braising. The percentage of loss attributed to the drippings was greater in the moist heat method than in the dry heat method. Taste panel scores indicated the cuts cooked by dry heat were significantly higher in aroma, flavor, and tenderness than the cuts cooked by moist heat.

Using a procedure called Roastasteak, Rodgers, Mangel and Baldwin preroasted (92) large cuts from rounds of beef to an internal temperature of 43°C. after which the meat was cooled. When needed for service, the meat was sliced and the slices were then broiled. This method was compared with meat prebrowned in a conventional broiler and then cooked in a 260°C. oven. The Roastasteak method was found to be more acceptable with the taste panel scoring it higher for juiciness and flavor than the cuts roasted to doneness in a 260°C. oven.

Lowe defined (68) the optimum cooking temperature as "the temperature that produces the most palatable product with a minimum weight and nutrient loss in a reasonable cooking time with a small amount of fuel." Based on a study of frozen and thawed roasts from beef, veal, lamb and pork, she stated (69) that the optimum oven temperature was 150 to 160°C. At oven temperatures of 120°C. or lower, cooking time was excessive and weight losses increased.

Methods of Holding Cooked Meats

Meat may be held sliced or unsliced over steam or dry heat prior to service in volume feeding operations. Partially or fully cooked meat may be refrigerated for varying periods of time and then sliced and reheated when needed for service. Few studies have been carried out to determine the effect of holding methods on the quality characteristics of meat.

Blaker and Ramsey investigated (8) the temperature at which roast beef was held in steam tables of four volume feeding operations. A small amount of surface drying was noted when unsliced roast beef was held for 2 hr. at an internal temperature of 60°C. However, slices of roast beef held in au jus showed evidence of surface drying after 15 min. Funk, Aldrich and Irmiter held (38) roasted short loins of beef for 6 and 18 hr. in a holding cabinet at a temperature of 60°C. Gaines, Perry and Van Duyne held (43) roasted top rounds of beef for 16 and 24 hr. at temperatures of 70 and 60°C., respectively, in an electric drying oven. Both studies indicated the quality of meat decreased as holding time increased. Meat loaves held in thermotainers for 2 hr. at 71°C. displayed drying on the top slices but no change in flavor was noted in a study by Gasson (44).

Vail and Westerman (108), conducting experiments on the effect of various heat treatments on the thiamine content of pork loin roasts, used two methods for holding the meat. For the first, a 30-min. holding period over steam was used to retain the heat in the sliced meat while roasts held by the second method were sliced and reheated for 36 min. in a 149°C. oven after refrigeration for 24 hr. The thiamine content of roasts analyzed after the 30-min. holding period was higher than that of roasts refrigerated and reheated. Lyon studied (73) the effect of grade and internal temperature on reheated top rounds of beef. The cooked meat was refrigerated for 17 hr., sliced, and then reheated for 30 min. in a 177°C. oven before it was held for 5 to 30 min. over dry heat. The sliced meat was judged to be acceptable in quality.

Factors Affecting Heat Transfer

During cooking

Cooking time for meat is usually stated in minutes per pound. This unit of measure can be used only as a guide since the variability of meat plus the many factors involved in heat transfer make it difficult to predict actual cooking time (68). The factors which affect heat transfer will be reviewed under the heading of composition, surface area/weight ratio, initial temperature and cooking methods.

Composition. The ratio and extent of heating are determined by the nature of the product being heated and are dependent on the consistency and homogeniety of the product (34). The composition of meat includes muscle, fat and connective tissue, and these components have a definite bearing on heat transfer.

Fat. In a study to determine the specific role of fat in the time required for beef to reach an internal temperature of 65°C., Thille, Williamson and Morgan cooked (106)

3-rib beef roasts at an oven temperature of 210°C. Their data revealed that a thick layer of exterior fat increased the rate of heat transfer because of the increase in heat conductivity of fat as it passed from the solid to the liquid condition. Roasts having thick and thin layers of surface fat exhibited cooking times of 19.3 and 23.4 min. per lb., respectively. Weir found (114) that internal temperatures of pork roasts increased independently of the thickness of fat cover except for roasts having a thin fat covering. Roasts with a 0.10-in. or less of fat cover showed an internal temperature rise of 1.08°C. per min. while those with 0.35-in. or more of fat cover had a rise of 0.92°C. per min.

Using meat cylinders fabricated from selected muscles of the round and containing approximately 2.5, 10, 20 and 30 per cent fat, Funk, Aldrich and Irmiter cooked (40) them to an internal temperature of 80°C. in a 121°C. forced convection oven. Total cooking time decreased as the fat content increased according to the results of the study. Lowe investigated (68) the rate of temperature rise in muscular and fatty tissue by filling four pint jars with lean beef, lean pork, fat pork and suet. With a thermometer bulb inserted in the center of each, the jars were heated in boiling water for 3 hr. The rate of temperature rise was most rapid in lean beef and decreased in the order of lean pork, fat pork and suet. Thille, Williamson and Morgan concluded (106) that internal fat may retard rates of internal temperature rise due to change in the heat conductivity of fat as it passes from the solid to the liquid state.

Surface Connective Tissue. Siemers and Hanning conducted (101) heat transfer studies using solid and minced suet as well as connective tissue of beef rounds. Connective tissue decreased the rate of heat transfer in solid blocks of suet more than in the samples where connective tissue had been minced or removed. Rates of temperature rise in equal volumes of connective tissue and intact suet were approximately the same.

Aging. Paul and Bratzler studied (86) the effect of two aging periods on the cooking times of steaks from the semimembranosus and adductor muscles of beef. Analysis of the data showed the cooking time for the deep fat cooked steaks decreased as the aging period increased.

Aging Leghorn broilers from 40 min. to 118 hr. after slaughter significantly decreased the cooking time according to a study by Hanson, Stewart and Lowe (51). This study is in accord with that of Alexander and Clark (4) who observed that less time was required to cook legs of lamb and mutton aged from 8 to 18 days than was needed to cook similar cuts aged from 2 to 6 days.

Surface area/weight ratio. As a piece of meat increases in size, its weight increases in greater ratio than its dimension.

If other conditions are standardized, large cuts will require fewer minutes per pound than small cuts (68).

Marshall, Wood and Patton reported (74) a study on the effect of size of beef roasts on the cooking time expressed in minutes per pound. Using 5-, 10- and 15-lb. roasts and an oven temperature of 149°C., they observed a decrease in minutes per pound with an increase in the weight of the roast.

Initial temperature. According to Lowe (68), a longer time is required for cooking when the initial temperature of meat is low than when it is high. For example, frozen meat requires a longer cooking time than refrigerated meat because part of the heat is used to melt the ice before the temperature is raised above the freezing temperature of meat (68). Cline *et al*. found (19) that beef roasts having an internal temperature of 1°C. required a longer cooking time than those with an internal temperature of 8 to 12°C.

Wanderstock and Miller showed (111) that frozen rolled rib roasts required a longer cooking time expressed in minutes per pound than similar fresh roasts. In a study by Child and Paul (16), frozen pork loin and standing beef roasts also took more time to cook than similar cuts thawed at 24 to 25°C. before cooking.

Cooking methods. Water, steam, air and fat are the standard media in which meat can be cooked. If the same temperature is being used for the cooking media, the cooking time depends on the speed at which heat is conducted in each medium (68).

Media. Cover compared (21) the rates of temperature rise of beef roasts cooked by dry and moist heat. The roasts simmered in water at 90°C. to an internal temperature of 80°C. took only 3 hr. to cook while similar cuts cooked at the same oven temperature took 23 hr. to reach the same internal temperature. Clark and Van Duyne concluded (12) that beef roasts cooked in a pressure saucepan required approximately one-third of the time that was needed to cook similar roasts in a 149°C. oven to the same internal temperature.

Cooking beef muscles in an oven and in deep fat, Visser *et al*. showed (109) that the roasts cooked in fat displayed more rapid rates of temperature rise. These results are in agreement with the findings of Lukianchuk (71) in which heat transfer was faster in roasts from selected muscles of beef rounds cooked in a fat medium than in similar roasts cooked in air to the same degree of doneness.

The use of metal skewers to shorten cooking times in an air medium has been investigated (80,23). Using 2-rib standing beef roasts, Morgan and Nelson observed (80) that skewers shortened the time required for the meat to reach an internal temperature of 51, 60 or 70°C. Shaw reported (100) conventionally cooked roasts from selected muscles of beef rounds required nearly twice as much time to reach an internal temperature of 80°C. as similar roasts cooked by the radial-conventional method in which heat was applied internally as well as externally.

In a study by Blaker, Newcomer and Stafford (7), aluminum foil was found to act as a thermal insulator. The investigators suggested a foil wrapping on beef roasts was equivalent to lowering the oven temperature by 42°C., thus increasing the cooking time.

<u>Time-temperature relationships</u>. Increased temperatures at the surface of meat result in increased rates of temperature rise to the interior, hence the higher the cooking temperature, the shorter the cooking time (68). Studying rates of temperature rise at low oven temperatures, Bramblett and Vail (10) reported that beef rounds cooked at 63 and 68°C. took an average of 12 and 8 hr., respectively, to reach an internal temperature of 57°C. Similar results were reported in a study by Alexander and Clark (3). In comparing methods of cookery, Funk, Aldrich and Irmiter noted (38) cooking time increased as the oven temperature decreased. Short loins of beef cooked in an 204°C. oven required an average of 109 min. to reach an internal temperature of 52°C. while the cooking time for similar roasts cooked at 149°C. averaged 141 min.

Marshall, Wood and Patton observed (75) a wide variation in rates of temperature rise in 10-lb. beef roasts cooked at oven temperatures of 93, 107 and 121°C. to internal temperatures of 60, 70 and 80°C. Differences in average cooking time were less for roasts cooked at 107 and 121°C. than for those cooked at 93 and 107°C. In cooking roasts from top rounds of beef, Hunt, Seidler and Wood observed (61) cooking time decreased significantly as successively higher oven temperatures were used. Time required to cook roasts also increased as more well done stages were attained.

In early studies on standing rib roasts, Latzke demonstrated (66) the internal temperature rise after the removal from the oven depended upon the internal temperature of the roast when removed from the oven. Roasts cooked to the same degree of donensss at different oven temperatures showed a rise directly proportional to the increase in oven temperature. Using 1- to 2-lb. beef roasts from the round, loin and tenderloin, Visser *et al*. found (109) no increase in internal temperature after removal from the oven when roasts were cooked at 149°C. to internal temperatures of 55, 70 and 85°C. Similar cuts cooked in deep fat at 110°C. to an internal temperature of 55°C. rose 10 to 13°C. while those cooked to 70°C. rose 5 to 6°C. A negligible rise was apparent in those cooked to 85°C.

During holding

Funk, Aldrich and Irmiter observed (38) rates of heat transfer during holding of roasts from short loins of beef. The meat was roasted in a 204°C. oven to 52°C. and then held for 6 and 18 hr. at 60°C. The average maximum temperature rise for the roasts was 16.5°C. At the end of 6 hr. of holding, their internal temperature dropped to 56°C. and no further changes were noted for the remainder of the 18 hr. holding period.

Using roasts from top rounds of beef, Gaines, Perry and Van Duyne compared (43) methods in which meat was seared at 217°C. for 1 hr. and held for 16 or 24 hr. at temperatures of 70 or 60°C., respectively. After a constant internal temperature rise during the first 6 hr., the roasts held 24 hr. had a mean internal temperature rise of only 4.8°C. The roasts held 16 hr. followed a similar pattern but to a lesser degree.

Blaker and Ramsey held (8) unsliced roasts on a steam table at a temperature of 60°C. They noted a rise in internal temperature for a 45-min. interval and thereafter, a slow decline. The roasts remained above 60°C. for 2 hr.

Factors Affecting Preparation Losses

During cooking

Total cooking losses of meat include both volatile and drip losses. Drip losses include fat, water, salts and both nitrogenous and non-nitrogenous extractives. Evaporation of water constitutes most of the volatile loss (68). Factors which influence cooking losses are composition, grade, aging, surface area/weight ratio as well as cooking time and method.

Composition. In the early 1900's, Grindley, McCormack and Porter showed (46) the chief weight loss of cooked meat was due to loss of water by evaporation. In a later study, Grindley and Mojonnier observed (47) that both water and fat constituted the weight loss of roasted meats.

Cooking rib roasts at 210^{o}C. to an internal temperature of 65^{o}C., Thille, Williamson and Morgan found (106) volatile losses in fat covered roasts were less than those from lean-surfaced roasts. However, fat covered roasts had higher total cooking losses than lean-surface roasts. In agreement with this study is the report of Lowe (68) in that evaporation losses decrease as the fat content of the meat increases.

There is a linear relationship between fat content and grade. Thus, the better grades of meat usually have increased fat losses (68). Studies by Alexander and Clark revealed (3) that higher grades of beef rib roasts had less evaporation losses and increased drip losses than lower grades regardless of the cooking method. Using beef rib roasts ranging from U. S. Choice to Canner grades, Alexander found (2) fat loss during cooking was directly related and water loss during cooking inversely proportional to the fat content of the meat. Drip losses averaged 3.7 to 0.4 per cent and evaporation losses averaged 6.5 to 10.9 per cent for U. S. Choice and Canner grades, respectively.

Masuda investigated (76) the effects of five different internal temperatures on cooking weight losses of tender cuts of U. S. Commercial, Good and Choice grades of beef when roasted at 149°C. Analysis of data showed no significant difference in total cooking or volatile losses attributable to grade. Drip losses, attributable to grade, differed significantly only when roasts were cooked to an internal temperature of 90°C. Roasts from U. S. Choice and Good grades showed higher drip losses than roasts from U. S. Commercial grade. Aldrich and Lowe cooked (1) U. S. Choice and Good grade roasts from beef rounds to an internal temperature of 90°C. in a 150°C. oven. No significant differences in cooking losses between grades were noted. Roasting the longissimus dorsi muscle from U. S. Good, Commercial and Utility grades of beef at 149°C. to an internal temperature of 80°C., Day reported (32) no significant differences attributable to grade in average total cooking, volatile and drip losses. Similar findings were reported by Hood (57).

Aging. Moran and Smith observed (79) that top and bottom round and loin roasts of beef ripened 3, 7 and 16 days showed a decrease in cooking losses as the ripening period increased. In accord with this study are the findings of Alexander and Clark (4) who pointed out that cooking losses decreased in legs of lamb and mutton with an increase in ripening time. Hanson, Stewart and Lowe noted (51) similar results in New York dressed broilers.

Griswold and Wharton reported (50) beef roasts stored for 9 days at 1.1°C. had greater evaporation and total cooking losses than similar roasts held for 37 days at the same storage temperature. For their study, rib roasts were cooked in a 150°C. oven to an internal temperature of 58°C. Paul, Lowe and McClurg stored (88) paired rounds of beef for 0, 1, 2, 4, 9 and 18 days. Total losses did not change significantly with storage time when the roasts were cooked at 150°C. to an internal temperature of 63 to 66°C.

Surface area/weight ratio. The shape of the meat cut of a given weight determines its surface area. Pieces with an irregular shape have an increased surface area and hence, greater losses than compact pieces with a small surface area (68).

Marshall, Wood and Patton reported (74) the size of roasts affects the total cooking losses. Losses from 5-lb. U. S. Choice grade roasts from beef rounds were significantly higher than losses from 10- and 15-lb. roasts when cooked to the same degree of doneness. Helser, Nelson and Lowe also noted (54) the total surface area greatly influenced cooking losses.

Cooking method and extent of cooking. Lowe stated (68) cooking method affected not only total but also the relative proportions of the various constituents lost during cooking. Hood cooked (58) boneless cuts of beef shoulder in an uncovered pan at 149°C. to an internal temperature of 77°C. Similar cuts were cooked in the same manner after wrapping in aluminum foil. Cooking losses, which were mainly drippings, were greater in the roasts which were wrapped in aluminum foil than those cooked by dry heat.

Bramblett and Vail wrapped (10) beef rounds in aluminum foil and cooked them to an internal temperature of 65°C. at oven temperatures of 68 and 93°C. Data analysis showed cooking losses were less for roasts cooked at 93°C. than for those cooked at 68°C. Funk, Aldrich and Irmiter reported (38) increased oven temperatures result in increased cooking losses. Loin cuts of beef roasted at 204°C. to an internal temperature of 52°C. lost an average of 19.18 per cent of their weight during cooking while similar cuts roasted at 149°C. to the same internal temperature lost only 12.49 per cent.

Cooking frozen and unfrozen rib roasts uncovered at 175°C. to an internal temperature of 58°C., Paul and Child reported (87) unfrozen roasts had significantly lower cooking losses than frozen roasts. These results indicate that the initial temperature of the meat influences cooking losses.

Grindley and Mojonnier found (47) losses to be greater when meat was roasted in a covered pan then when cooked in uncovered pans although less time was required to cook the meat in the covered pan. These findings are in agreement with those of Grindley, McCormack and Porter who observed (46) that losses depend on cooking time. After roasting cuts from beef rounds at an oven temperature of 150°C. to an internal temperature of 90°C., Aldrich and Lowe reported (1) an additional hour of cooking increased average total weight loss from 34.5 to 38.9 per cent and average volatile loss from 18.0 to 27.2 per cent.

Latzke observed (66) that cooking losses increased as the degree of doneness or internal temperature increased. Losses also increased proportionally to rise in oven temperature from 13.52 per cent for roasts cooked at 110°C. to 22.49 per cent for roasts cooked at 175°C. Marshall, Patton and Wood found (74) total cooking losses increased with the degree of doneness only to the medium well-done stage. Using oven temperatures of 120 and 150°C., Lowe _et al_. showed (69) roasts cooked to an internal temperature of 58°C. had lower cooking losses than similar cuts cooked to an internal temperature of 75°C.

Hunt, Seidler and Wood stated (61) analysis of their data showed five different oven temperatures did not significantly affect total cooking losses of 10-lb. roasts from top rounds of beef. However, many researchers have reported (2,3,17,18) high oven temperatures increase cooking losses. High oven temperatures produced cooking losses of 30.44 per cent as compared to 6.79 per cent with low oven temperatures in a study by Cline _et al_. (19). Bramblett _et al_. noted (9) roasts from beef rounds cooked at an oven temperature of 63°C. averaged 23.7 per cent cooking losses as compared with 27.9 per cent for roasts cooked at oven temperatures of 68°C.

<u>During holding</u>

In a study by Funk, Aldrich and Irmiter (38), roasts cooked at 204°C. and then held 6 and 18 hr. at 60°C. were found to have average drip losses during holding of only 0.31 per cent. This small percentage was probably due to the 60°C. temperature of the holding cabinet which was too low to render out fat. Average volatile losses during holding were 13.10 and 15.91 per cent for roasts held 6 and 18 hr., respectively.

Gaines, Perry and Van Duyne observed (43) roasts held 24 and 16 hr. had higher evaporation and total cooking losses than similar roasts which were not held. Roasts held for 24 and 16 hr. at 60 and 70°C., respectively, had total losses of 19.1 and 17.7 per cent, respectively.

Factors Affecting Thiamine Retention

Meat is an excellent source of thiamine (81). However, its retention is affected by thawing, cooking and holding procedures.

<u>Thawing</u>

Pearson <u>et al</u>. ascertained (90) the percentage of thiamine lost when drip obtained from frozen beef was discarded. The longissimus dorsi muscle was dissected from rib steaks, frozen at -17.8°C. and then thawed for 14 to 15 hr. at approximately 26°C. Data analysis revealed the drip contained 1.13 mcg. thiamine per milliliter and hence, 12.23

per cent of the total amount of thiamine in the meat was lost in the drip.

Using frozen round steaks, Westerman et al. studied (115) the effect of four different methods of thawing on thiamine retention. Steaks were thawed at room temperature, in the refrigerator, in a warming oven at 73°C. and under running tap water before they were braised in a covered pan at an oven temperature of 191°C. Significant difference was noted in thiamine content of meat thawed by the four methods. When total retention of thiamine in the meat and drip was considered, losses were greatest when the meat was thawed in water.

Cooking

Thiamine is a heat labile vitamin. In general short cooking times and low cooking temperatures favor its retention (36). Besides time-temperature relationship, its retention is also influenced by cooking method and surface area/weight ratio.

Cooking methods. Comparing beef round and loin steaks broiled at 200°C. with those braised at 100°C., Cover and Smith found (30) thiamine retention significantly higher in the broiled steaks than in the braised steaks. They reported figures of 59 and 36 per cent thiamine retention for broiled and braised steaks, respectively. Comparing rib roasts cooked in a 150°C. oven to an internal temperature of 80°C. with similar cuts braised to an internal temperature of 93°C., the same investigators found oven roasts retained 41 per cent thiamine as compared with a 49 per cent retention in the braised roasts. They concluded that evaporation from the surface of the roast during dry heat cookery or washing from the surface by moist heat cookery could be an important factor affecting the retention of thiamine.

Fenton *et al*. browned (37) U. S. Choice and Utility grade beef chuck and round roasts at 160°C. for 2 min. on both sides and then braised them in a 149°C. oven to an end-point temperature of 98.3°C. Similar cuts were braised at 10 lb. of pressure and a temperature of 116°C. to an internal temperature of 102°C. Significant differences in thiamine retention were noted between these two methods of cooking for both grades of meat. Oven braised roasts retained 39 per cent thiamine for both grades while U. S. Choice and Utility grade cuts which were pressure braised retained 31 and 25 per cent, respectively.

Clark and Van Duyne cooked (12) cuts from top rounds of beef at 148.9°C. to an internal temperature of 82°C. and in a pressure cooker at 15 lb. pressure and a temperature of 121°C. Total thiamine retention was 22 and 39 per cent for oven roasted and pressure braised roasts, respectively. Using selected muscles of the round, Noble found (81) roasts braised in a 149°C. oven to an internal temperature of 85°C. retained 40 per cent of their original thiamine content.

The cooking liquid contained 25 per cent of the thiamine originally present in the raw sample.

Time-temperature relationships. Investigating the effect of oven temperature on thiamine retention, Noble and Gomez roasted (82) rib cuts of beef in a 177°C. oven while their pairs were cooked in a 149°C. oven to the same end-point temperature of 71°C. Data analysis revealed no significant difference in thiamine retention when the two oven temperatures were used for cooking. Drippings had a negligible thiamine content. However, Cover *et al*. found (25) paired rib roasts cooked at 150 and 205°C. to an internal temperature of 80 and 98°C., respectively, retained 61 per cent at the low oven temperature and 47 per cent at the high oven temperature. Lushbough *et al*. observed (72) roasts from beef rounds cooked in 93 and 149°C. ovens to an internal temperature of 60°C. gave similar values for thiamine retention in the inner but not the outer portion of the cut. In the same study, thiamine retention decreased significantly in both the inner and outer portions when the meat was cooked at an oven temperature of 204°C. After autoclaving at 121°C. for 4 hr., similar cuts retained 5.4 per cent thiamine. No thiamine was detected after 16 hr. of autoclaving. Cover, McLaren and Pearson showed (27) 2-rib beef roasts cooked at oven temperatures of 150°C. retained 75 and 69 per cent thiamine when cooked to internal temperatures of 60 and 80°C., respectively.

Surface area/weight ratio. In comparing thiamine retention in pork loin roasts and chops, Vail and Westerman found (108) roasts cooked in a 176.7°C. oven to an internal temperature of 82.2°C. and chops braised to 83°C. had average thiamine contents of 14.7 and 14.2 mcg per gram, respectively. However, the percentage of thiamine retained in the roast was lower because the uncooked roast showed a higher thiamine content than the uncooked chops. They concluded this difference may have been due to the size of the cut. Aughey and Daniel reported (5) pork loin roasts cooked at an oven temperature of 175°C. to an internal temperature of 84°C. lost 43 per cent of their thiamine value while braising pork chops resulted in a 15 per cent loss of thiamine.

Holding

Vail and Westerman observed (108) thiamine retention in pork loin roasts treated by various holding methods. Sliced roasts held over steam for 30 min. retained 91 per cent of the thiamine which was present in cooked meat while those held overnight at a temperature of 4.4°C. retained 92.8 per cent of the thiamine present in freshly cooked roasts. Roasts held overnight, sliced and reheated retained 93.1 per cent of the thiamine present in the roasts after holding overnight and 90.3 per cent of thiamine present in the freshly cooked meat. Holding top rounds of beef for 16 and 24 hr. at 70 and 60°C., respectively, Gaines, Perry and Van Duyne noted (43) a thiamine retention of 83.5 and 92.4 per cent.

Factors Affecting Palatability Characteristics

Meat palatability is defined by such quality characteristics as aroma, flavor, color, juciness and tenderness. These characteristics are important in the appeal and acceptance of meat by the consumer.

Aroma, flavor and color

Meat flavor and aroma are very difficult to describe and evaluate (114). As with color, they are influenced by the composition, method and extent of cooking and method and extent of holding.

Composition. The palatability characteristics of meat are determined by the muscle, fat and bone of which meat is composed. E. C. Crocker stated (31) cooking of meat developed a meaty flavor due to the chemical changes in the fiber. Cooked meat flavor is predominately odor according to Crocker. However, Kramlich and Pearson observed (64) flavor components are located primarily in the juice and that full flavor develops when the juice and fiber are heated together.

Using beef rounds, Simone, Carroll and Clegg found (103) differences in the degree of finish and carcass grade resulted in differences in flavor. They suggested flavor was associated with intramuscular fat. In agreement with this study is that of Hornstein and Crowe who reported (60) the characteristic aroma of heated lamb is obtained from the fat. Lean meat portions contribute a basic meaty flavor similar to that obtained from lean beef and pork.

Cooking selected muscles from the rounds of Choice, Good and Commercial grade beef, Masuda noted (76) average aroma and flavor scores for U. S. Commercial grade roasts were significantly higher than scores from similar roasts taken from U. S. Good and Choice grade animals. Analyzing data obtained from roasts taken from the longissimus dorsi muscle of U. S. Good, Commercial and Utility grades of beef, Day found (32) significant differences attributable to grade for aroma and flavor. In contradiction, Knopf and Graf observed (63) carcass grade did not affect flavor.

Paul *et al*. investigated (89) the relationship of bone to flavor in beef roasts and steaks. The investigators found significant differences attributable to bone in average scores for flavor of fat and lean of rib, chuck and rump roasts as well as club, Porterhouse and sirloin steaks.

According to Weir (114), the color of cooked lean meat depends upon the nature and amount of myoglobin derivatives as well as decomposition products that are present. The pink color in cooked rare meat is due to oxymyoglobin while the brown color of completely cooked meat is due to a number of pigments including denatured heme compounds and polymerization of carbohydrates, fats and proteins.

Method and extent of cooking. Selecting both tender and less tender beef muscles, Visser *et al*. roasted (109) meat in a 149°C. oven to internal temperatures of 55, 70 and 85°C. and cooked similar cuts in deep fat at 110°C, to the same internal temperatures. They noted the appearance of deep fat cooked roasts was gray-brown in color while the oven roasted cuts were a rich brown in color.

Comparing selected muscles of the round cooked to an internal temperature of 80°C. by conventional oven roasting and deep fat immersion, Lukianchuk found (71) a slight preference for flavor of oven roasted meat but the average scores for aroma were identical for samples cooked by both methods. Scores for color favored samples cooked in deep fat.

Shaw observed (100) no significant differences in aroma, flavor or color scores for selected muscles of beef rounds roasted by conventional and radial-conventional methods to an internal temperature of 80°C. However, average scores for the three characteristics were highest for the conventionally cooked roasts. A study by Morgan and Nelson showed (80) 2-rib roasts cooked with metal skewers were more appetizing in appearance than similar roasts cooked without skewers.

Using top round beef roasts, Blaker, Newcomer and Stafford cooked (7) aluminum foil-wrapped roasts to 63°C. in a 260°C. oven while similar unwrapped cuts were cooked in a 177°C. oven to the same internal temperature. Unwrapped roasts were scored highest in aroma, internal flavor and color. The foil-wrapped roasts possessed a distinct steamed appearance and flavor. Bramblett _et al_. observed (9) selected muscles of the round cooked in aluminum foil wraps at an oven temperature of 63°C. for 30 hr. were scored higher in appearance than roasts cooked in aluminum foil wraps for 18 hr. at an oven temperature of 68°C.

In a comparative study, Clark and Van Duyne roasted (12) cuts from top rounds of beef at 148.9°C. to an internal temperature of 82°C. and cooked similar cuts in a pressure saucepan at 121.1°C. to the same end-point temperature. The study revealed roasted cuts were more palatable with a better flavor for fat and lean while meat cooked in the pressure saucepan was rated dry and less palatable. Rodgers, Mangel and Baldwin preroasted (93) cuts from beef rounds to an internal temperature of 43°C. after which the meat was refrigerated. To prepare it for service, the meat was sliced and then broiled. Flavor scores for meat cooked by this method were higher than those for similar cuts that were prebrowned and then cooked in a 260°C. oven.

Hood, Thompson and Mirone observed (59) cuts from selected muscles of the round cooked by dry heat methods scored significantly higher in aroma and flavor than similar cuts cooked by moist heat methods. However, Cover and Shrode found (29) rib, round and chuck beef roasts cooked at 150°C. to an end-point temperature of 80°C. were scored lower by the judges than similar cuts braised to 98°C. in a 100°C. oven.

Roasting cuts of beef round to 85°C. at oven temperatures of 121 and 149°C., Griswold concluded (48) the roasts cooked at 121°C. appeared dark and hard on the surface but were more acceptable in flavor than those cooked at 149°C. In accord with this study is that of Steck and West (104) who noted that an oven temperature of 121°C. resulted in chuck roasts with good flavor. Cline *et al*. found (19) rib cuts of beef decreased in flavor as oven temperature used for roasting increased. However, in a later study, Cline, Loughead and Schwartz observed (18) no difference in palatability of rib and chuck roasts cooked at 125 and 155°C. Latzke concluded (66) that the maximum flavor and color are obtained for rib roasts when they are cooked at an oven temperature of 125°C. to an end-point temperature of 61°C.

Investigating roasts from beef rounds cooked at oven temperatures of 93, 107 and 121°C. to internal temperatures of 60, 70 and 80°C., Marshall, Wood and Patton observed (75) that as the degree of doneness increased appearance scores were lowered but flavor scores were similar for all internal temperatures. Aldrich and Lowe noticed (1) scores for aroma and flavor decreased when pot roasts from beef rounds were cooked for an additional hour at 150°C. to an internal temperature of 90°C.

Method and extent of holding. In a study reported by Funk, Aldrich and Irmiter (38), beef loin roasts were held for 6 and 18 hr. after cooking to an internal temperature of 52°C. in a 204°C. oven. The fat and exposed lean surfaces appeared dry at the end of the holding periods. Aroma scores for the roasts which were held were significantly higher than aroma scores from similar roasts which were not held. Differences noted in color between held and unheld roasts were highly significant with the held roasts having little pink color and hence, the lowest scores. Holding did not significantly affect flavor of lean scores, but judges indicated the fat had a burned flavor at the end of the 18-hr. holding period.

Gaines, Perry and Van Duyne showed (43) conventionally cooked roasts to be more palatable than roasts which were browned and then held for 24 or 16 hr. at 60 and 70°C., respectively. After holding unsliced roast beef on a steam table for 2 hr., Blaker and Ramsey observed (8) surface drying.

Juiciness

The juiciness of cooked meat is first, the impression of wetness during the first chews produced by the rapid release of meat fluids and second, sustained juiciness apparently due to the slow release of serum and the stimulating effect of fat on the salivary flow (115). Juiciness is influenced by composition, animal characteristics, method and extent of cooking and holding.

Composition. According to Weir (114), well marbled meat from a mature animal with a relatively high degree of finish is juicier than that of a young animal with less marbling. Gaddis, Hankins and Hiner observed (42) the scores for quality and quantity of juice for rib cuts cooked at 149°C. to an internal temperature of 60°C. were influenced by the amount of intramuscular fat. Percentage of press fluid tended to decrease as the fat content increased. Cooking beef ribs to 65°C. at an oven temperature of 210°C., Thille, Williamson and Morgan reported (106) the fat-surfaced beef roasts were less dry than the lean-surfaced roasts.

Using selected muscles of the round from U. S. Good, Commercial and Utility grade animals, Day roasted (32) them at 149°C. to an internal temperature of 80°C., and noted that press fluid tests did not reveal a significant difference in juiciness attributable to grade. Similar results were reported by Masuda (76) in her study using U. S. Choice, Good and Commercial grades of beef. In agreement with these studies is that of Knopf and Graf (63) who found the carcass grade of loin strip steaks did not affect the juice yield. Simone, Carroll and Clegg showed (103) differences in juiciness became more apparent when differences were greater in the degree of finish and carcass grade.

A comparison of juice yield of bone-in and boned roasts cooked under standardized conditions by Lowe _et al_. revealed (69) a smaller amount of press fluid in the boned roasts than in the bone-in roasts. Child and Esteros cooked (14) standing rib roasts and rolled rib roasts to 58°C. at an oven temperature of 149°C. Their data pointed out a significant difference in juiciness between these two cuts with the standing rib roast containing more juice. Similar conclusions were reached by Noble, Halliday and Klass (83) who reported a greater juice yield from standing rib roasts when both were cooked to 61°C. at an oven temperature of 149°C.

Cover, Ritchey and Hostetler studied (28) the effect of connective tissue of the longissimus dorsi muscle of beef on juiciness. Analysis of the data showed connective tissue did not appear to interfere with juiciness scores.

Animal characteristics. Tuma *et al*. noted (107) juiciness of cooked beef was not influenced by the age of the animal. More flavorful and juicy meat is normally associated with older animals but was not found to be true in this study (107). Simone, Carroll and Chichester also observed (102) no relationship between juiciness and age.

Using three age groups of beef, Walter *et al*. investigated (110) the palatability characteristics as affected by the age of the animal. They reported the longissimus dorsi muscle of beef decreased in juiciness as the age of the animal increased.

Method and extent of cooking. Juiciness of meat is greatly affected by the cooking method, oven temperature and time. Moderate oven temperatures usually result in juicier meat unless it is cooked for long periods. Rare beef is normally juicier than well done beef (114).

Hood cooked (58) paired beef shoulder roasts at 149°C. to an internal temperature of 77°C. after one of each pair had been wrapped in aluminum foil. Highly significant differences in juiciness were found for roasts cooked by these two methods with the highest scores recorded for roasts cooked without the aluminum foil wrap. Using paired roasts from beef rounds which were wrapped in aluminum foil and cooked at oven temperatures of 68 and 93°C. to an internal temperature of 65°C., Bramblett and Vail reported (10) the panel scores were significantly higher for the roasts cooked at 93°C. Bramblett _et al_. found (9) higher taste panel scores for juiciness in foil-wrapped beef round roasts cooked for 30 hr. at 63°C. than for their pairs cooked similarly for 18 hr. at 68°C.

A comparison of cooking selected muscles of beef rounds in a 149°C. oven and in deep fat at 115°C. to the same end-point temperature of 80°C. by Lukianchuk revealed (71) meat cooked in deep fat was significantly lower in juiciness as determined by both objective and subjective evaluations than the oven cooked meat. In a similar study, Visser _et al_. cooked (109) tender and less tender cuts of beef in deep fat at 110°C. and in a 149°C. oven to the same end-point temperatures of 55, 70 and 85°C. They noted as the degree of doneness increased juiciness decreased.

Comparing conventional and radial-conventional methods, Shaw cooked (100) selected muscles of beef rounds at 149°C.

to an internal temperature of 80°C. Analysis of variance showed no significant differences in juiciness attributable to cooking method with judges favoring the juiciness of radial-conventional cooked samples. Skewered rib cuts of beef roasted to internal temperatures of 51, 60 and 70°C. were noted to have more juice than unskewered similar cuts roasted under the same conditions, according to a study reported by Morgan and Nelson (80).

Hood, Thompson and Mirone observed (59) no significant difference in juiciness scores of less tender cuts of beef rounds cooked by dry heat methods or braising. Clark and Van Duyne reached (12) similar conclusions when they cooked roasts from beef rounds in a 148.9°C. oven to an end-point temperature of 82°C. and similar cuts in a pressure sauce-pan at 121.1°C. to the same end-point temperature.

Marshall, Wood and Patton found (75) the degree of doneness had a highly significant effect on juiciness. Scores for juiciness decreased as the internal temperature increased. In agreement with this study is that of Sanderson and Vail (94) who reported various muscles of U. S. Good and Choice grade beef cooked at 104°C. to internal temperatures of 60 and 70°C. and at 121°C. to an internal temperature of 80°C. displayed a highly significant difference in press fluid due to the internal temperature. Satorious and Child (95), Seidler and Wood (97), Ho and Ritchey (57), and Child and Fogarty (15) reached similar conclusions.

Cooking roasts from rounds of beef at oven temperature of 121 and 149°C., Griswold noted (49) the roasts cooked at 149°C. were more juicy. Lowe *et al*. observed (70) little difference in juiciness of beef rib roasts cooked at oven temperatures of 120 and 150°C. when the same internal temperature was used to indicate doneness. Cline *et al*. pointed out (19) a decrease in juiciness with increased oven temperatures. Using oven temperatures of 125 and 155°C., Cline, Loughead and Schwartz found (18) rib, chuck and sirloin tip roasts all ranked the same for juiciness. Aldrich and Lowe observed (1) that an additional hour of cooking for pot roasts at 150°C. after they had reached an internal temperature of 90°C. brought about a decrease in juiciness.

Method and extent of holding. Funk, Aldrich and Irmiter found (38) roasts held for 18 hr. at 60°C. had lower scores for juiciness than similar roasts which were not held. When a 6-hr. holding period was used, juiciness scores did not differ significantly from those of unheld roasts.

Gaines, Perry and Van Duyne noted (43) the differences between juiciness scores for held and unheld roasts were small. The unheld roasts had lower juiciness scores than roasts held for 16 hr.

Tenderness

Studies have shown that tenderness is the most important palatability factor in the acceptance of beef. Composition, nimal characteristics, method and extent of cooking as well s subsequent holding are factors which influence the tenderess of beef.

omposition. Finish and marbling have a direct influence on the degree of tenderness even though the amount of fat is not invariably associated with the tenderness of beef (70). Lowe also pointed out (68) the deposition of intramuscular fat increases the tenderness of the meat. In a study of 334 beef carcasses representing a wide range of grades, Knopf and Graf found (63) tenderness of the lean increased as the external and internal finish increased. Investigating the effect of intramuscular fat on the tenderness of 25 muscles from beef carcasses, Ramsbottom and Strandine found (91) no significant correlation between fat content and tenderness of the muscle. They concluded there was no significant relationship between intramuscular fat and shear force readings of raw or cooked samples.

Comparing tender and less tender cuts of beef, Lowe and Kastelic failed (70) to find any relationship between tenderness and connective tissue in the meat. Carcass grade and marbling had little practical relationship to the tenderness of connective tissue of longissimus dorsi and biceps femoris beef muscles in a study by Cover and Hostetler (26). Hiner, Anderson and Fellers observed (55) collagenous and elastic fibers influenced the tenderness in beef muscle heated to 60°C. but exactly how was not made clear.

Knopf and Graf experimented (63) with U. S. Choice nd Commercial grade beef carcasses to determine the relaionship between grade and tenderness. Carcass grade was ioted to have a highly signigicant effect upon tenderness as letermined by mechanical and sensory evaluation. Webb, Kahlenberg and Naumann showed (113) tenderness scores for U. S. Choice and Cutter grade beef carcasses exhibited no significant differences but the shear force value indicated that Choice grade was significantly more tender than Cutter grade. Fenton et al. noted (37) objective measurements indicated U. S. Choice grade beef to be more tender than Utility grade beef. Similar conclusions were reached by Day (32) and Masuda (76).

Animal characteristics. Many researchers (26,53,57,112) have investigated the relationship between animal age and tenderness. Webb, Kahlenberg and Naumann studied (113) 30 cattle of ages 12, 34 and 60 mo. Loin steaks of the 60-mo. old cattle were found to be less tender than 12- and 24-mo. old cattle as determined subjectively and objectively. Investigating animals from ages 2 1/2 to 5 1/2 yr., Hiner and Hankins concluded (56) that as the animal matured there was a decrease in tenderness. In accord with this study is that of Harrison et al. (53) who noted beef cuts from 8-yr.-old cows were less tender than similar cuts from 14- to 16-mo.-old steers. However, Helser, Nelson and Lowe observed (54) in the longissimus dorsi muscle of 8-, 20-, and 32-mo.-old cattle, tenderness was not influenced greatly by age. Ho and Ritchey found (57) only when the longissimus dorsi muscle from 3-mo.- to 2-yr.-old beef was cooked to 80°C. did tenderness increase as age increased.

Satorious and Child reported (95) the longissimus dorsi muscles from cows graded good and steers graded high medium to good were homogeneous in tenderness. Knopf and Graf observed (63) loin steaks from steer carcasses showed lower tenderness ratings than those from cows and heifers. Contrary to this study, Cline, Loughead and Schwartz pointed out (18) that roasts from cows scored lower in tenderness than those from steers and heifers.

Animal muscles vary widely in tenderness. The most tender muscles are those containing the least connective tissue and those with the largest amount of connective tissue are the least tender (114).

Ramsbottom, Strandine and Koonz studied (91) 25 representative muscles from U. S. Good grade beef carcasses. After cooking them in lard at 121.1°C. to an internal temperature of 76.7°C., they noted tenderness varied from muscle to muscle as measured by shear force values. Comparing U. S. Good grade semimembranosus, semitendinosus and biceps femoris muscles, Ginger and Weir observed (45) within muscles there was a significant variation in tenderness. Paul and Bratzler showed (85) the anterior end of the longissimus dorsi beef muscle was more tender than the posterior end. Bramblett *et al.*

reported (9) significant differences in the tenderness of five muscles of beef rounds as measured objectively. Shear values revealed no significant differences in tenderness of the semimembranosus and biceps femoris muscles of beef in a study by Griswold (49).

Using a modified New York Laboratory Penetrometer, Noble, Halliday and Klass concluded (83) cooked rib cuts of beef were more tender than cooked round cuts from the same animal.

Method and extent of cooking. The cooking processes generally change muscle tenderness by producing changes in structural proteins and/or connective tissue of the meat. Muscle differences and the effect of different cooking methods explain why some cuts become more tender and others less tender during cooking (113).

Studying the effect of cooking methods on tenderness of low grade beef rounds, Hood, Thompson and Mirone noted (59) meat cooked by dry heat was more tender than similar cuts which were braised. Clark and Van Duyne detected (12) no difference in tenderness determined by mechanical shear or subjective judging in beef roasts from the round cooked in a 149°C. oven to an internal temperature of 82°C. and their pairs which were cooked in a pressure saucepan at 121.1°C. to the same end-point temperature. Cover cooked (21) beef roasts in water at 90°C. for 3 hr. and their pairs in a 90°C. oven for 23 hr. to the same internal temperature. Shear values and panel scores indicated oven roasts to be more tender. She concluded the presence of moisture around the cooked meat appeared to be unsuccessful in making the meat tender.

Using the semimembranosus muscle of beef round, Lukianchuk reported (71) roasts cooked in deep fat had a slightly lower shear force reading than similar cuts cooked in a 149°C. oven to the same internal temperature. Visser et al. reached (109) the same conclusion when testing comparable methods of cookery.

Shaw roasted (100) semitendinosus muscle of beef round by conventional and radial-conventional methods in a 149°C. oven to an internal temperature of 80°C. Analysis of the data revealed a highly significant difference in tenderness attributable to the method of cooking with average scores for tenderness favoring conventionally roasted samples. Cooking beef rib roasts with and without skewers, Morgan and Nelson found (80) skewered roasts to be more tender than unskewered roasts.

Bramblett et al. cooked (9) muscles from beef rounds at 63 and 68°C. for 30 and 18 hr., respectively, in aluminum foil wraps. Time-temperature relationships had an effect on meat tenderness in that the length of time the meat was held between 57 and 60°C. related to an increase in tenderness. Cooking foil-wrapped muscles of beef round at oven temperatures of 68 and 93°C. to an internal temperature of 65°C., Bramblett and Vail showed (10) scores and shear values indicated meat cooked at 68°C. to be more tender.

Cover noted (22) rib roasts cooked at an oven temperature of 80°C. to an internal temperature of 70°C. were more tender than similar cuts cooked at an oven temperature of 125°C. to the same internal temperature. The longer time required for heat to penetrate the roasts at the lower oven temperature may have contributed to an increase in tenderness according to the study. Cline *et al*. pointed out (19) that tenderness decreased as oven temperatures increased when rib roasts were cooked to 57°C. at oven temperatures of 110, 125, 163, 191, 218, and 260°C.

Hunt, Seidler and Wood found (61) no significant differences in tenderness of roasts from beef rounds cooked at 135, 149, 163, 177 and 190°C. to internal temperatures of 60, 70 and 80°C. Contrary results were reported by Marshall, Wood and Patton (75) who found tenderness increased as the internal temperature of the meat increased.

Method and extent of holding. Funk, Aldrich and Irmiter noted (38) average tenderness scores were significantly higher for roasts held 18 hr. and conventionally cooked roasts than for roasts held for 6 hr. However, no significant difference attributable to holding was noted by shear force measurements.

Using top round beef roasts, Gaines, Perry and Van Duyne compared (43) two delayed service methods of roasting with conventionally cooked roasts. Significantly less shearing force was required for the conventionally cooked roasts than for similar cuts held for 24 and 16 hr. at 60 and 70°C., respectively.

Methods for Determining Palatability

Palatability can be determined either objectively or subjectively. Subjective evaluation employes the use of the senses while objective measurement is determined by physical and chemical means (68).

Subjective evaluation

Subjective evaluation of food involves the senses of sight, smell and taste. Acceptance or rejection of food depends mainly on the stimulus of the sense organs of the individual (68).

Scoring tests. According to Lowe (68), the scoring test is used more frequently than any other sensory test. The judges assign a numerical rating to the quality characteristic using descriptive terms to qualify the scores.

In the evaluation of meat, flavor, tenderness, juiciness, color and odor are the chief factors scored by a taste panel (68). A 7-point scale as suggested by the Cooperative Meat Investigation Committee is the most commonly used.

Chew count. Chew count is a partly objective and partly subjective method used to determine the tenderness of meat. The number of chews required to masticate a meat sample to a pre-determined end-point are recorded. This number is then compared to an established score chart.

Harrington and Pearson investigated (52) the use of the chew count as a measure of tenderness of pork loins with various degrees of marbling. Significant correlations were observed between chew counts and shear values. They also noted the chew count is of value mainly if no large deposits of connective tissue are present in the sample.

Objective measurements

The combined effects of physical and chemical properties of meat determine meat quality. Since the organoleptic properties of meat depend to a certain extent upon the physical characteristics, objective determination of the physical characteristics has been studied (68).

Juiciness. Objectively, juiciness is determined by the amount of expressible fluid in the meat (100). As early as 1934, Child and Baldelli developed (13) a pressometer to remove press fluid from roasted beef muscle. In 1943, Tanner, Clark and Hankins used (105) a hydraulic press maintained at 9800 lb. of pressure for 5 min. to determine press fluis of a 36-gm. meat sample.

The Carver Press is a widely used laboratory apparatus for determining the press fluid of a meat sample. Up to 24,000 lb. of pressure can be applied to the meat sample in order to extract the fluid. Use of the Carver Press by Shaw

(100) and Lukianchuk (71) revealed significant correlations between press fluid and juiciness scores of meat.

Tenderness. Although several mechanical means have been devised to measure tenderness, one of the most recent and modern instruments used is the Kramer shear-press. It employes the use of hydraulic pressure to force a series of metal plates through a shear cell containing the meat sample. The force is recorded and then converted into pounds force per grams of meat (65).

In a study of broad breasted Bronze turkeys by Dodge and Stadelman (33), use of the Kramer shear-press revealed that cooked meat should be used for research evaluation of meat tenderness. Sharrah, Kunze and Pangborn noted (99) that mechanical devices differ in sensitivity and reproducibility. Comparing the Kramer shear-press with the Warner-Bratzler shear, they observed that the latter correlated more highly with scores for tenderness than did the former. Bramblett and Vail (10), Rodgers, Mangel and Baldwin (92), Shannon, Marion and Stadelman (98), Bailey *et al.* (6), Burrill, Diethardt and Saffle (11) and Funk, Aldrich and Irmiter showed (38) a significant correlation between the Kramer shear-press values and tenderness scores. Similar conclusions were reached by Parrish, Bailey and Naumann (84) who also found a correlation between hydroxyproline content of meat and Kramer shear-press values.

METHOD OF PROCEDURE

To compare the effects of three methods of holding on the palatability characteristics, weight losses and thiamine retention, 24 loin cuts from 6 pairs of U. S. Choice grade beef loins were used. After cooking, roasts were held unsliced and sliced over dry heat for 90 min. Cooked roasts were also refrigerated for approximately 24 hr. before slicing and then reheating for service. Samples which served as the control were served immediately. Procedures used for cooking and holding as well as objective measurements and sensory evaluations were developed through preliminary investigations.

Procurement of Samples

U. S. Choice grade, Range 2, boneless strip loin, short cuts, prepared as outlined in the Meat Buyer's Guide to Standardized Meat Cuts, Item No. 180 (105) were procured through a local wholesaler. Each strip loin cut was halved to obtain two roasts.

The roasts were coded according to the animal from which they were obtained, anterior or posterior position, side of the animal and the holding treatment to be used. Codes were arbitrarily assigned so three of the four cuts from each animal were held by a different method with the fourth cut used as a control. Samples from the anterior and posterior positions and left and right sides were rotated according to a predetermined plan (Table 1).

Table 1. Rotation plan for meat cuts used as a control and held by three methods.

Treatment	Code and Rotation Plan for the Twenty-four Meat Cuts					
Control	1PR,	2AR,	3AL,	4PL,	5PR,	6AR
Held unsliced	1AR,	2AL,	3PL,	4PR,	5AR,	6AL
Held sliced	1AL,	2PL,	3PR,	4AR,	5AL,	6PL
Chilled and reheated	1PL,	2PR,	3AR,	4AL,	5PL,	6PR

Code: Animal, 1 to 6; Position, A-anterior, P-posterior; Side of animal, L-left, R-right.

The roasts were wrapped in polyethylene film and waxed freezer paper. They were frozen and stored at -23°C. until needed for evaluation.

Preparation of Samples for Roasting

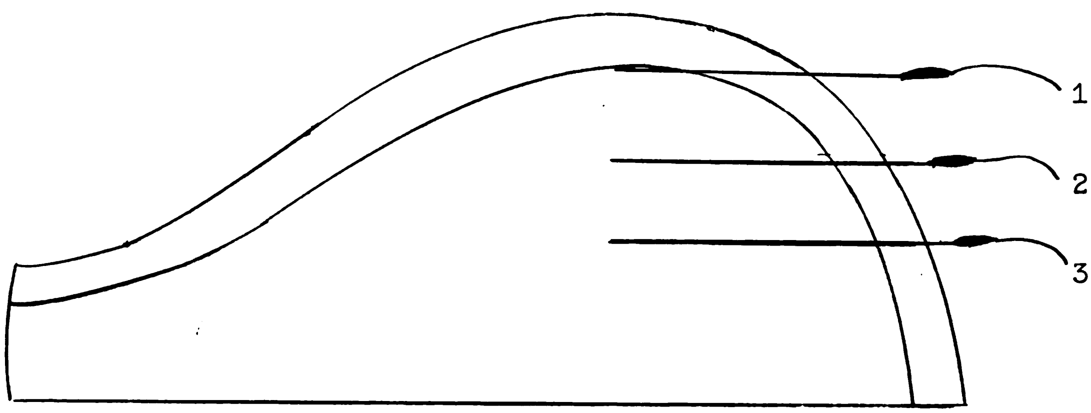
The roasts were defrosted in a reach-in refrigerator at 5°C. for 24 hr. They were then unwrapped and the surface fat was trimmed to 0.50-inch in thickness as measured with a vernier caliper. Samples for pH and thiamine analyses were removed from the anterior of roasts coded A and from the posterior of roasts coded **P**. The roasts were then weighed on a 5-kg. capacity torsion balance.

The roast was placed on an aluminum sheet roasting rack perforated with 3/8-in. holes at 0.75-in. x 0.50-in. intervals. The 18" x 9.50" x 1" roasting rack had previously been weighed in an 18" x 9.75" x 2.25" aluminum roasting pan.

Three iron constantan thermocouples were positioned in the roast from the center of the back (Fig. 1). The first potentiometer lead was positioned at the center of the muscle tissue; the second, midway between the center of the muscle tissue and the fat, connective tissue interface; and the third just below the surface fat and the connective tissue sheath covering the muscle tissue. The potentiometer leads were connected to a 12-point Brown Electronic Potentiometer High Speed Multiple Recorder which continuously recorded the time-temperature relationships at each position during cooking.

Roasting of Meat

The samples of meat were roasted according to a predetermined schedule. Depending on the holding method used, one or two roasts were cooked simultaneously in the same oven. Roasts held unsliced and sliced for 90 min. were cooked simultaneously while roasts served immediately and roasts which were refrigerated and reheated were cooked independently. A Hotpoint deck oven, model HJ225, equipped with a



1. Fat, connective tissue-muscle interface
2. Muscle tissue
3. Center of muscle

Figure 1. Potentiometer lead positions for continuous recording of time-temperature relationships during roasting.

Honeywell Versatronik controller, was preheated to and maintained at 149°C. ± 1° with the grids set on medium and the dampers half closed.

All roasts were cooked to an internal temperature of 54°C. as measured by the potentiometer lead positioned in the center of the muscle tissue. Preliminary investigations showed roasts cooked to this temperature were at the desired rare stage of doneness when sliced and served.

Treatment after Removal from Oven

After removal from the oven, all roasts stood undisturbed for 30 min. at room temperature to reach their maximum internal temperature. Potentiometer leads were then removed and the roasts were weighed. The weight of the pan, rack, and probe holder and drip were also recorded. The following treatments were then applied.

Control

The roast was sliced on a Hobart slicer model 410 set at 22 to give slices of 0.25-in. thickness. The slices were placed in a warmed half-counter pan according to a predetermined pattern (Fig. 2). The weight and number of slices were recorded and unused scrap defined as incomplete slices was weighed. After the meat was removed from the pan for subjective evaluation, the weight of the pan plus the drip was recorded.

	Extra slices
	Carver press
	Kramer shear-press 1
	Kramer shear-press 2
	Taste panel member 1
	Taste panel member 2
Posterior	Taste panel member 3
	Taste panel member 4
	Temperature during holding
	Taste panel member 5
	Taste panel member 6
	Taste panel member 7
	Thiamine analysis
	pH
	pH
	Thiamine analysis
	Taste panel member 7
	Taste panel member 6
	Taste panel member 5
	Temperature during holding
	Taste panel member 4
Anterior	Taste panel member 3
	Taste panel member 2
	Taste panel member 1
	Kramer shear-press 2
	Kramer shear-press 1
	Carver press
	Extra slices

Figure 2. Diagram indicating the position from which slices for subjective evaluations and objective measurements were taken from roasts in the anterior and posterior positions of each loin of beef.

Holding procedures

The meat was held by three different methods; unsliced, sliced and refrigerated overnight and then reheated. The basis for the selection of these methods has been discussed in the introduction.

Unsliced. The roast was placed in a weighed, coded and warmed counter pan. After inserting a potentiometer lead into the center of the meat to record the time-temperature relationships, the pan was covered with aluminum foil and a second counter pan inverted over the first to serve as a cover. The roasts was held over dry heat for 90 min. in a General Electric Rocket Food Warmer, model CF11, with the dial set on 3, thus maintaining a temperature of 106^{o}C. ± 10^{o} on the floor of the warmer. Upon removal from the warmer, the roast was weighed. Weight of the counter pan plus the drip was also recorded. After slicing, the weights of the slices and scrap were determined.

Sliced. The roast was treated in the same manner as the control except that after slicing it was held 90 min. over dry heat with the dial of the warmer set at 5, thus maintaining a temperature of 137^{o}C. ± 5^{o} on the floor of the warmer. A potentiometer lead was positioned into a slice as indicated in Figure 2 to record the time-temperature relationships during holding. The half-counter pan was covered with aluminum foil with another half-counter pan inverted and used as a cover. After 90 min., the weight of the pan plus the sliced meat was recorded and when the meat was removed from the pan, the pan and drip were weighed. The number of slices as well as the weight of scrap was determined.

Refrigerated overnight and reheated. The roast was placed in a coded and weighed counter pan and a potentiometer lead was positioned in the center of the meat before it was covered with aluminum foil and an inverted counter pan. The meat was then refrigerated and time-temperature relationships were recorded until the internal temperature of the meat dropped to approximately 5^{o}C. Upon removal from the refrigerator the following day, the roast was weighed as was the pan in which it had been held. After slicing, the meat was placed in a warmed, weighed and coded half-counter pan and weighed. The number of slices was recorded and unused scrap was weighed. A potentiometer lead was positioned in a slice as indicated on the chart (Fig. 2) to record time-temperature relationships. With aluminum foil covering the pan, the sliced meat was reheated to an internal temperature of 60^{o}C. in a 149^{o}C. $\pm$ 1^{o} oven. Weight of the pan plus drip was recorded after the meat was removed for subjective evaluation.

Cooking losses

Total, drip and volatile cooking losses were calculated for each roast and converted to percentages based on the raw weight of the sample. Oven cooking losses were calculated as the difference in raw and cooked weight. The weight of the drip was obtained by subtracting the weight of the roasting pan and rack from the total weight of the pan, rack and drip. Volatile losses were calculated as the difference in total oven cooking losses and drip losses.

Other losses

Total, drip and volatile holding losses were calculated for each roast and converted to percentages based on the raw weight of the sample. Drip loss was calculated as the difference in pan weight before and after holding. For refrigerated and reheated roasts, the drip losses were calculated as the difference in pan weight before and after holding in the refrigerator. Volatile losses for holding meat unsliced were obtained by subtracting from the weight of cooked meat before holding, the weight of the cooked meat after holding and the drip loss. Volatile losses for holding sliced or refrigerated roasts were obtained by determining the difference in weight of the meat in the pan before and after holding.

Total, drip and volatile reheating losses were calculated for roasts refrigerated and reheated and converted to percentages based on the raw weight of the sample. Drip reheating losses were obtained by subtracting the weight of the pan before reheating from the weight of the pan after reheating. Volatile reheating losses were calculated as the difference in the weight of the sliced meat before and after reheating.

Percentages for slicing losses based on the raw weight of the sample were also calculated for each roast. Slicing losses were found by subtracting the weight of the slices plus the weight of the scrap from the cooked weight of the meat.

Accumulative losses for cooking, slicing, holding and reheating were determined and converted to percentages based on raw weight of the sample. These percentages were expressed as total, total drip and total volatile losses.

Evaluation of Samples

After cooking and any subsequent treatment, samples of meat were subjectively evaluated. To further assess the effects of holding or reheating on the quality characteristics, chemical and objective measurements were determined. Slices of meat for these determinations were taken from the same relative positions in each of the 24 roasts as illustrated in Figure 2.

Subjective evaluations

A taste panel consisting of seven trained judges subjectively scored samples from each roast for quality and intensity of aroma, color of lean, quality and intensity of flavor of lean, quality and intensity of flavor of fat, juiciness, and tenderness using a 7-point scale. A score of 1 indicated unacceptable quality and a score of 7 showed excellent quality. Descriptive terms aided the judges in their evaluations. The temperature of the sample was also rated on a numerical scale with 1 indicating hot; 2, warm; and 3, cold. A copy of the score card as well as the instructions given to the judges appears in the Appendix.

The panel was trained at two preliminary sessions. A room with special lighting and in which all conditions could be kept constant was used throughout the study. A glass of water at room temperature and unsalted crackers were provided for the panelists to use between the evaluation of the two samples served at each session to eliminate any meat or fat flavors from their mouths.

Tenderness scores were based on chew counts as determined from a 1-in. circle of meat, precut from the meat slice before serving. Each judge counted the number of chews required for the meat circle to disappear from his mouth without consciously swallowing it. During preliminary sessions, the number of chews corresponding to a tenderness score was determined for each panelist and a chew chart was then used as a guide by each judge for scoring tenderness.

Each judge received a slice of meat from the same relative position in each roast (Fig. 2). The samples were served as soon as possible after the cooking, holding or reheating treatment on white plates coded with random numbers. The temperature of the meat sample was maintained by using Dri-heat hot plate assemblies which consisted of a stainless steel bottom shell which held a preheated pellet made from an aluminum alloy, the serving plate and a stainless steel cover. The pellets were preheated for 2 hr. in a 204°C. oven while the bottom, plate and cover of the Dri-Heat assembly were warmed in the oven of a Frigidare range, model RDG34-59, for 2 hr. with the dial set on warm.

Objective measurements

Slices of meat for objective measurements were taken from the same relative positions in each roast (Fig. 2). The slices were wrapped in Saran and cooled to room temperature before juiciness and tenderness were determined.

Juiciness. The Carver Laboratory Press was used to determine the juiciness of the samples. Two samples, weighing from 7.2 to 11.6 gm., were cut from the designated slice and weighed to the nearest 0.0 gm. on a Mettler balance, model Pl 1000. Samples were placed between canvas and felt pads and a pressure of 15,000 lb. per sq. in. was applied simultaneously to two samples for 10 min. The samples were then removed from the pads and reweighed. After conversion to percentages of press fluid, the two values for each roast were averaged.

Tenderness. The Kramer shear-press, model SP12, was used to measure the tenderness of the meat. Using a 2.25 in. square cutter, a sample was cut from each of the two designated slices and each was weighed on a Torbal balance, model Pl-900, to the nearest 0.00 gm. The sample was placed in the center of the standard shear compression cell. Using a

30-sec. downstroke, 20 lb. range, 250 lb. pressure and a 3000-lb. proving ring, the sample was sheared. The pounds of force required to shear the meat sample were recorded on a time force curve by a Varian electronic indicator, model EZEZ. The maximum force per gram was calculated as:

$$\frac{\text{Maximum peak percentage x Range percentage x Ring}}{\text{Sample Weight}}$$

The area covered by the time-force curve was determined by weighing the curve which had been carefully cut from the chart paper to the nearest 0.0000 gm. The weight was then multiplied by the factor, 174.2, to convert it to an area of square centimeters, as outlined by Funk, Zabik and Downs (41). The two determinations of maximum force per gram and of the time-force curve were each averaged to indicate tenderness for each roast.

Chemical analysis

Samples for pH from the raw and cooked, held or re-heated meats were wrapped in Saran and left at room temperature until the determinations were made. For thiamine determinations, samples were placed in labeled sample jars and frozen at -23°C. until analyzed.

pH. A 10-gm. sample of raw or cooked meat was combined with 100 ml. of distilled water in a Waring blender, model PB-5A, and blended for 3 min. as controlled by a GraLab timer, model 171. The slurry was strained through a fine wire sieve into 2 150-ml. beakers for duplicate readings. A Beckman Zeromatic pH meter, model 9600, with a glass electrode was used to read the pH of the slurries. Duplicate readings were averaged to determine the pH of each sample.

Thiamine analysis. Samples were analyzed for thiamine according to the procedure of Mickelsen and Yamamoto (78). The procedure was modified by increasing the amount of 2.0 N HCl during hydrolysis of the sample with a subsequent readjustment of the pH to 3.9 after incubation if necessary. For analysis of the raw meat, a sample from the anterior and posterior positions of the same animal were pooled. Cooked samples from four roasts for each treatment were analyzed. Triplicate determinations of each sample were made using 4, 6 and 8 gm. of ground meat for the analysis. The results of the three determinations were averaged. A grand mean was obtained by averaging the results for the four replications of each treatment. Thiamine content was expressed in micrograms per gram of sample.

Analyses of the Data

All data from subjective evaluations and objective measurements were analyzed using statistical routines for the CDC 3600 computer at Michigan State University. Time-temperature relationships were averaged for cooking and any subsequent treatment applied.

Statistical procedures

The data were subjected to analysis of variance to determine significant differences attributable to treatment. Data were also analyzed for differences among animals because of possible animal variations. Duncan's Multiple Range test was used (35) to pinpoint the significant differences found in the analyses of variance. Correlation coefficients were determined for all possible combinations of the data. Means and standard deviations for subjective evaluations and objective measurements were also computed.

For analyzing the data from subjective evaluations, scores of the seven judges were averaged for each quality characteristic evaluated in each roast to minimize variance due to judges. Using the average taste panel scores, analyses of variance were then computed.

Time-temperature relationships

During oven cooking, the time-temperature relationships were recorded at three points within each roast by a recording potentiometer. At 10-min. intervals, the temperature for each of the three points for all 24 roasts was averaged as were the temperatures during the 30-min. standing period after the roasts were removed from the oven. However, temperatures recorded during the 30-min. standing period were averaged separately from the cooking period. Average cooking time and the average maximum interval temperature were also determined for the 24 roasts.

The time-temperature relationships for holding the meat for 90 min., unsliced and sliced, were averaged for 10-min. intervals for the six replications of each of the two holding methods. For the refrigerated and reheated roasts, the time-temperature relationships were averaged during the cooling period at 1-hr. intervals. The average cooling time was also determined. During reheating, the time-temperature relationships were averaged at 10 min. intervals. The average reheating time was also determined.

RESULTS AND DISCUSSION

The purpose of this study was to compare the effects of selected times and temperatures during the holding and/or reheating on the quality characteristics and thiamine retention of short loins of beef. Cooked roasts were served immediately, held unsliced and sliced over dry heat for 90 min. or refrigerated for 24 hr. and then sliced and reheated. Subjective and objective data were analyzed statistically for significant differences attributable to treatment and to animals. Heat transfer data were also examined for the various holding methods.

Heat Transfer

Time-temperature relationships were recorded during cooking, holding and reheating of loin cuts of beef. The data for cooking, holding unsliced and sliced meat over dry heat and reheating sliced meat were averaged at 10-min. intervals. For roasts held at refrigerated temperatures, the data were averaged at 1-hr. intervals until the temperature recorded from the center of the roasts was the same as the refrigerator temperature.

<u>During cooking</u>

All roasts were cooked in a 149°C. oven to an internal temperature of 54°C. During oven cooking and the 30-min. standing period following removal from the oven, time-temperature relationships were recorded from three potentiometer leads positioned within each roast. The mean time-temperature relationships of the 24 roasts were determined for each of the three positions within each roast and the data were plotted (Fig. 3). The average cooking time was 93 min.

The potentiometer lead positioned just below the connective tissue and surface fat which covered the roast recorded the most rapid rate of temperature rise throughout the cooking period. During the first 20 min. of the cooking time, the temperatures recorded from the center of the muscle tissue and from a point midway between the center and the connective tissue, exterior fat-muscle interface were approximately the same. After that time, temperatures recorded from the center of the muscle tissue exceeded those recorded from the point midway between the center and the connective tissue, exterior fat-muscle interface. These data suggest heat penetrated the roasts at a more rapid rate from the bottom than from the top of the roasts. The physical characteristics of the roasts, such as the surface fat and connective tissue on the top of the roasts, may have affected rates of temperature rise. The 1/2-in. fat covering increased the depth which the heat had to penetrate. Other investigators have suggested

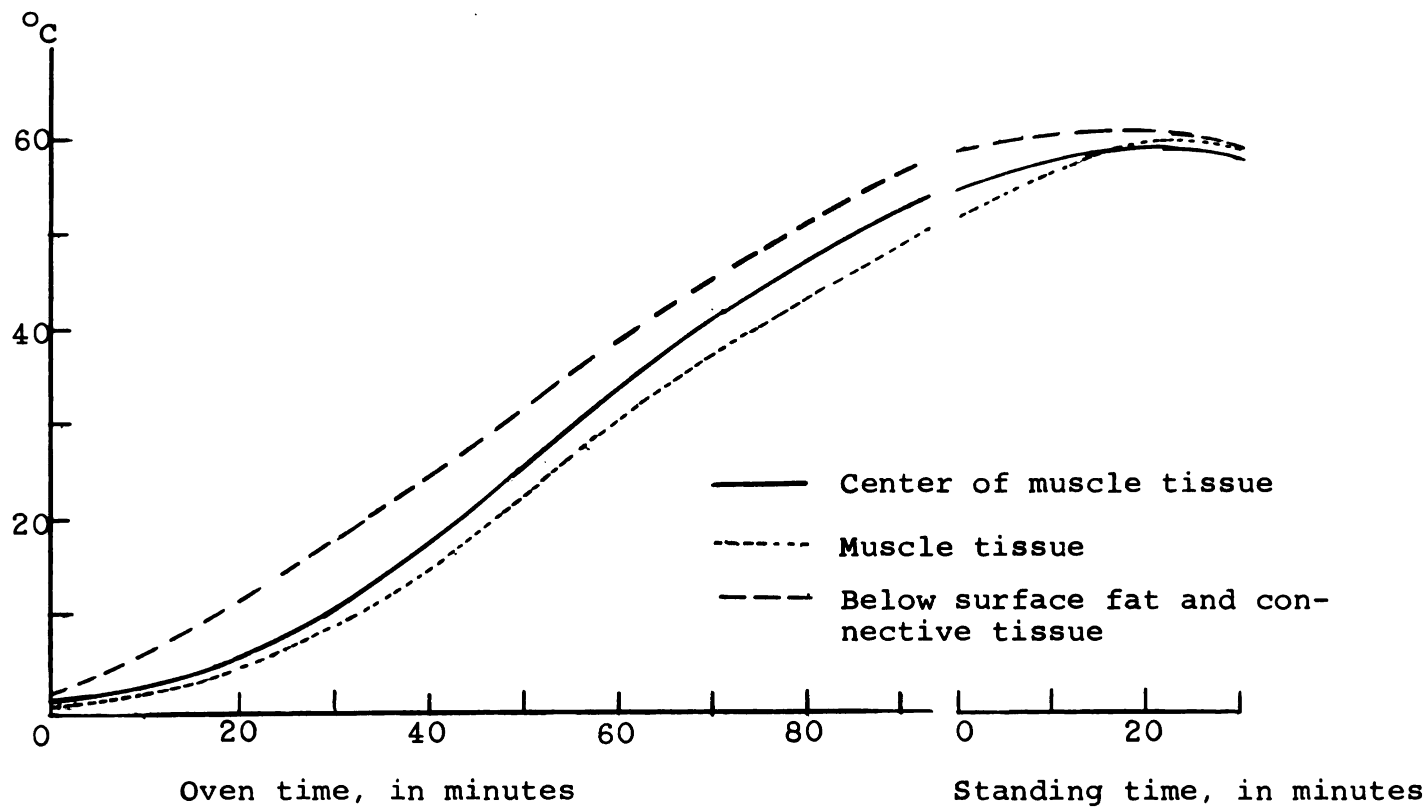


Figure 3. Mean time-temperature relationships for 24 roasts during oven cooking and a 30-min. standing period for three points within each roast.

the exterior fat and connective tissue may decrease rates of temperature rise. Funk, Aldrich and Irmiter reported (39) an exterior covering of fat increased the time necessary to cook fabricated ground beef cylinders to the rare stage of doneness. In another study by the same investigators (40), connective tissue apparently retarded rates of temperature rise during the beginning phase of the cooking period. Seimer and Hanning also found (98) connective tissue decreased rates of temperature rise. Also, in the present study the lower surface of the boned roasts rested on a perforated aluminum sheet roasting rack. Because metal is a better conductor of heat than air, this factor would contribute to the rates of temperature rise observed in this study.

During the 30-min. standing period following removal from the oven, the average maximum temperature as recorded from the potentiometer lead positioned in the center of the muscle tissue reached 60°C., an average rise of 6°C. Heat from the surface of the meat continued to penetrate into the inner portion during the first 22 min. of the standing period. After that time, the temperature showed a slight decline. The temperature recorded from the connective tissue, exterior fat-muscle interface reached a maximum of 61°C. after the first 7 min. of standing and by the end of the 30-min. standing period, it had dropped to 59°C.

<u>During holding</u>

A potentiometer lead was positioned in the center of the muscle tissue of unsliced roasts to record time-temperature relationships during the 90-min. holding period over dry heat. The mean temperature recorded during the investigation showed the average initial temperature of the meat was 55.5°C. or 4.5°C. lower than the temperature recorded at the end of the 30-min. standing period following cooking (Fig. 4). These data suggest the meat cooled slightly during the process of weighing to determine cooking losses and preparing it for the holding period or the potentiometer lead was not placed in the same position used to record time-temperature relationships during oven cooking. During holding, the temperature rose to an average of 58°C. indicating heat transfer from the environment into the roast.

For the roasts held sliced, a potentiometer lead was positioned through the surface fat to the center of the previously designated slice (Fig. 2, page 52). During the investigation, the average temperature of the meat rose from an initial temperature of 48.5°C. to an average of 59°C. (Fig. 4). At the end of the 30-min. standing period following oven cooking, the average temperature of the meat had been 59°C. Thus, during preparation for holding, the temperature decreased an average of 10.5°C. However, at the end of the 90-min. holding period, the average meat temperature had increased to 59°C. or 10.5°C.

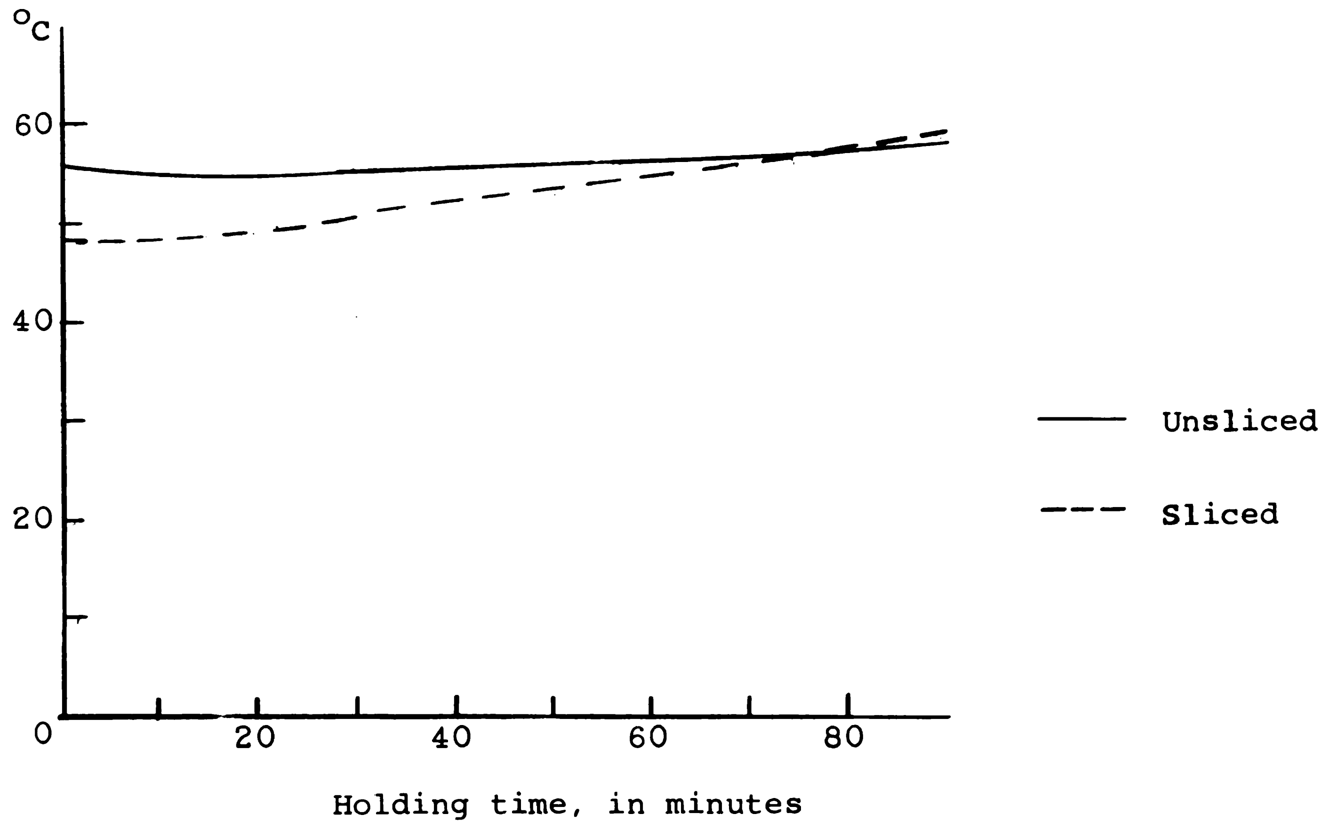


Figure 4. Mean time-temperature relationships for roasts held unsliced and sliced for 90 min. over dry heat.

For roasts refrigerated for approximately 24 hr., time-temperature relationships were recorded from a potentiometer lead positioned in the center of the roast. As indicated in Figure 5, the average decline in temperature was from 56.5°C. to 4.5°C. The average time required for the meat to reach this temperature was 7 hr. and 48 min. The temperature decreased most rapidly during the first 2 hr. of the cooling period while the slowest rates of heat transfer were noted for the final 3 hr. of the cooling period.

During cooling, the internal temperature of the meat remained in the "danger zone" or a temperature of 4.5 to 60°C. for 7 hr. and 48 min. In a review of time-temperature control for foods, Longree suggested (67) cooling times for solid foods such as meat may be largely anticipated on the basis of experience rather than scientific knowledge because limited data are available on heat transfer in solid foods. The results of this study support Longree's suggestion.

<u>During reheating</u>

During reheating, time-temperature relationships were recorded from a potentiometer lead positioned in the previously designated slice (Fig. 2, page 52). The temperature of the meat increased 1°C. during slicing and preparation for reheating. The rate of temperature rise during reheating shows a very slight initial lag followed by a continuous rapid rate of temperature rise over the average 67.2 min. required to heat the sliced meat to 60°C. (Fig. 5). Moisture

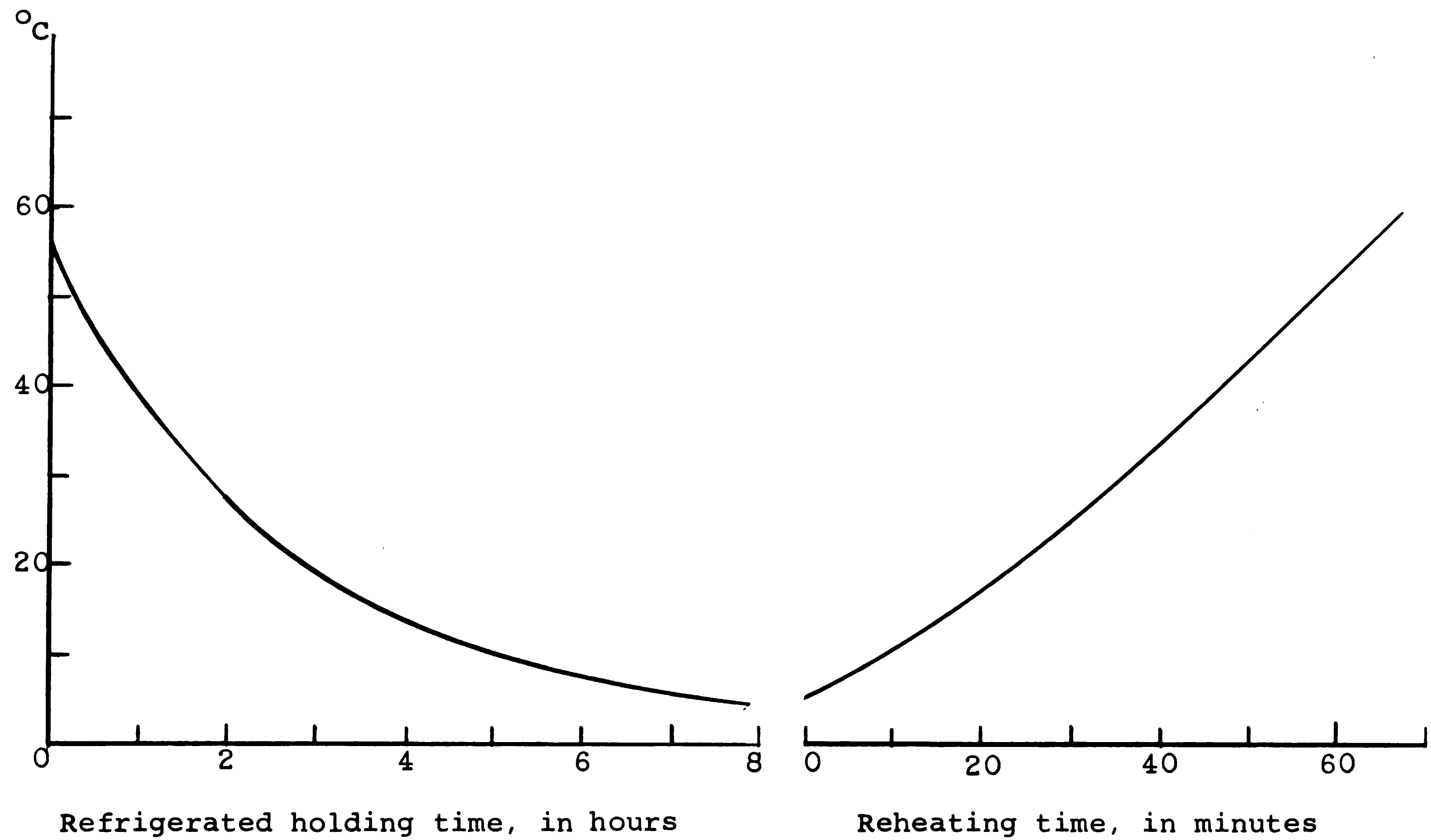


Figure 5. Mean time-temperature relationships for roasts held unsliced in a refrigerator for 24 hr. and then reheated after slicing.

present in the covered pan would increase rates of temperature rise because the moisture would form steam as it was heated and steam conducts heat more rapidly than air.

Weight Losses

Data pertaining to cooking, holding, reheating and slicing losses were calculated as percentages based on the raw weight of the meat. When possible, the portion of losses attributable to drip and to evaporation were determined, Means and standard deviations were computed for weight losses, servable meat and scrap for each treatment (Table 2). Analyses of variance of losses, servable meat and scrap are found in Table 3. Further analysis as shown by Duncan's Multiple Range test are summarized (35) in Table 4. Percentages of cooking losses for six replications of roasts served immediately and held by the three methods are found in the Appendix, Table 15. Data for other losses are presented in the Appendix, Table 16.

Cooking losses

The procedure for oven cooking plus the 30-min. period during which the roasts were allowed to stand undisturbed at room temperature after removal from the oven was the same for all roasts. Hence, total, drip and volatile losses did differ significantly among treatments. Also, there were no significant differences in these losses among animals. Grand average total cooking losses were 12.62 per cent with

Table 2. Means and standard deviations for weight losses, servable meat and scrap of roasts served immediately and held by three methods.

	Treatment			
	Control 1	Unsliced 2	Sliced 3	Refrigerated and Reheated 4
Total cooking losses	12.32±1.80	12.48±2.29	12.92±2.34	12.77±1.05
Total holding losses	---	4.01±1.64	7.98±0.82	1.64±0.22
Slicing losses	4.34±1.34	2.68±0.64	1.29±0.10	0.41±0.06
Servable meat	76.29±3.68	68.23±5.14	65.14±6.67	58.86±1.01
Scrap	10.23±2.82	14.06±4.58	12.67±5.27	14.11±2.46

Table 3. Analyses of variance for weight losses, servable meat and scrap of roasts served immediately and held by three methods.

		Mean Square				
Source of Variance	Degrees of Freedom	Total Cooking Losses	Total Holding Losses[1]	Slicing Losses	Servable Meat	Scrap
Total	23					
Treatment	3	0.451	61.500**	17.427**	315.031**	19.866
Animal	5	2.664	0.530	0.837	7.105	11.006
Error	15	4.132	2.079	0.650	26.104	17.248

[1]Analysis of variance computed for the three holding methods. Degrees of freedom are 2, 5 and 10 for treatment, animal and error, respectively.

**Significant at the 1 per cent level of probability.

Table 4. Duncan's Multiple Range test[1] for significant differences in weight losses from roasts served immediately (1), held unsliced (2), held sliced (3) and refrigerated and reheated (4).

	Significant at $P \leq 0.01$	Additional at $P \leq 0.05$
Total holding losses	3 > 2 > 4	
Slicing losses	1 > 2 > 3 > 4	
Servable meat	1, 2 > 3, 4	1 > 2

[1]Values underscored by the same line are not significantly different (35).

4.21 and 8.41 per cent attributable to drip and volatile losses, respectively. These results are in agreement with those reported by Funk, Aldrich and Irmiter (38) and Child and Esteros (14). Percentages of total, drip and volatile cooking losses for six replications of all treatments are presented in the Appendix, Table 15.

<u>Holding losses</u>

Analysis of variance revealed highly significant differences among treatments for total holding losses. Further analysis showed total holding losses were significantly higher ($P \leq 0.01$) for roasts held sliced than for roasts held unsliced and these in turn were significantly higher ($P \leq 0.01$) than total losses incurred during refrigerated holding. Average total holding losses of 7.98, 4.01 and 1.64 per cent were found for roasts held sliced and unsliced over dry heat and unsliced in the refrigerator, respectively.

Mean values of 2.27, 7.84 and 0.74 per cent were found for roasts held unsliced and sliced over dry heat and unsliced refrigerated roasts, respectively, for loss due to drip. These losses differed significantly with roasts held sliced having significantly higher ($P \leq 0.01$) drip losses than roasts held unsliced which in turn were significantly higher ($P \leq 0.01$) than those of roasts held unsliced in the refrigerator. The high drip losses of roasts held sliced were probably due to the increased surface area which would permit more juice to drain from the meat during the 90-min. holding period. Other researchers have reported increased cooking losses when roasts have been cooked in moist heat. Hood found (58) cooking losses, which were mainly drip, were greater in roasts cooked in aluminum foil wraps than cooking losses or roasts cooked by dry heat. At the refrigerator temperatures, fat would congeal rather than render from the meat and perhaps the congealed fat would prevent other drip from accumulating during the refrigerated holding. Hence, low drip losses resulted when the roasts were held in a refrigerator.

Analysis of variance revealed no significant differences among treatments or animals for volatile holding losses. Roasts held sliced had the highest average volatile loss of 1.74 per cent. Unsliced roasts held over dry heat or refrigerated had average volatile losses of 0.50 and 0.90 per cent, respectively. All pans in which roasts were held were covered with aluminum foil before the lid was placed on the pan. This procedure was followed because potentiometer leads used to record time-temperature data did not permit a tight fit of pan lids. Therefore, volatile losses were minimized during holding and similar losses resulted from the three treatments.

<u>Reheating losses</u>

Roasts which had been refrigerated for approximately 24 hr. were sliced and reheated in a 149°C. oven to an internal temperature of 60°C. During the average 67.2-min. reheating period, average losses of 12.38 per cent resulted. Of that total, 11.88 per cent was due to drip and 0.49 per cent was due to evaporation. As was done for holding periods, pans of meat were covered with aluminum foil before the lid was placed on the pan. This procedure apparently minimized volatile losses during reheating.

<u>Slicing losses</u>

After slicing, the slices of meat were placed in a pan to facilitate serving or to hold or reheat. Some drip accumulated during this process. For roasts served immediately and roasts held unsliced, this drip was weighed and the amount added to losses due to slicing. For roasts held unsliced, similar losses were included in drip losses incurred during holding while for unsliced refrigerated roasts, these losses were included as a part of those attributable to reheating.

Analysis of variance of slicing losses showed highly significant differences among treatments. However, slicing losses due to animal differences were not significant. Roasts served immediately had significantly higher ($P \leq 0.01$) slicing losses than roasts held unsliced. The slicing losses from roasts held unsliced were significantly higher ($P \leq 0.01$) than those of roasts held sliced and these in turn were significantly higher ($P \leq 0.01$) than the slicing losses of roasts refrigerated and reheated.

Slicing losses were lowest for roasts refrigerated and reheated with a mean loss of 0.41 per cent. Means of 4.34, 2.68 and 1.29 per cent were found for roasts served immediately, roasts held unsliced and roasts held sliced, respectively. The low slicing losses of refrigerated roasts would be expected because the congealed fat would hold in the juices of the meat. Also, the firmness of the chilled roasts would contribute to lower slicing losses.

<u>Accumulative losses</u>

For roasts served immediately, these losses consisted of cooking and slicing losses while total losses for roasts held unsliced and sliced included those attributable to cooking, holding and slicing. Total losses for roasts refrigerated and reheated consisted of cooking, holding, slicing and reheating losses. The percentages of the total losses due to drip and evaporation are defined in the same manner.

Means and standard deviations were computed for accumulative losses (Table 5). Analyses of variance for the accumulative losses are shown in Table 6. Further analysis as found by the Duncan's Multiple Range test are summarized (35) in Table 7.

Total losses. Analysis of variance showed highly significant differences among treatments for total losses. However, no significant differences attributable to animal were noted. Upon further analysis, roasts served immediately had significantly lower ($P \leq 0.05$) average losses than roasts held unsliced. Roasts served immediately and roasts held unsliced had significantly lower ($P \leq 0.01$) average total losses of 16.66 and 19.20 per cent, respectively, than roasts held sliced with the average total losses of 22.19 per cent. These losses were significantly lower ($P \leq 0.01$) than the 27.19 per cent average total losses of the roasts refrigerated and reheated.

Total drip losses. Analysis of variance revealed significant differences ($P \leq 0.01$) in total drip losses due to treatment but none among animals. Roasts served immediately and roasts held unsliced had significantly lower ($P \leq 0.01$) average total drip losses of 8.33 and 8.99 per cent, respectively, than

Table 5. Means and standard deviations for accumulative losses from roasts served immediately and held by three methods.

	Treatment			
	Control	Sliced	Unsliced	Refrigerated and Reheated
Losses	1	2	3	4
Total	16.66±0.97	19.20±1.54	22.19±2.01	27.19±1.86
Drip	8.33±0.94	8.99±1.01	13.23±1.11	17.43±1.44
Volatile	8.34±1.34	10.21±1.09	8.96±1.30	9.76±1.13

Table 6. Analyses of variance for accumulative losses from roasts served immediately and held by three methods.

Source of Variance	Degrees of Freedom	Mean Square: Total Losses	Mean Square: Total Drip Losses	Mean Square: Total Volatile Losses
Total	23			
Treatment	3	122.878**	107.167**	4.150
Animal	5	1.703	0.843	1.857
Error	15	3.039	1.454	1.357

**Significantly different at the 1 per cent level of probability.

Table 7. Duncan's Multiple Range test[1] for significant differences in accumulative losses for roasts served immediately (1), held unsliced (2), held sliced (3) and refrigerated and reheated (4).

Losses	Significant at $P \leq 0.01$	Additional at $P \leq 0.05$
Total	$\underline{1,\ 2} < 3 < 4$	$1 < 2$
Drip	$\underline{1,\ 2} < 3 < 4$	
Volatile	Not significant	

[1]Values underscored by the same line are not significantly different (35).

similar losses from roasts held sliced with an average total drip loss of 13.23 per cent. These losses were significantly lower ($P \leq 0.01$) than the 17.34 per cent average drip losses incurred by roasts refrigerated and reheated. Explanations for differences in drip losses have been discussed.

Total volatile losses. Mean percentages for total volatile losses of 8.34, 10.21, 8.96 and 9.76 per cent were found for roasts served immediately, roasts held unsliced and sliced and roasts refrigerated and reheated, respectively. Analysis of variance revealed no significant differences attributable to treatment or animals.

Servable Meat and Scrap

The amount of meat available for serving was defined as the weight of all whole slices of meat obtained from each roast. Partial slices were defined as scrap. Percentages of servable meat and scrap, based on the raw weight of the sample, are presented in the Appendix, Table 17.

The refrigerated and reheated roasts yielded 58.86 per cent servable meat which was the lowest amount for the four treatments. Roasts held sliced and unsliced yielded similar percentages of 65.14 and 68.23, respectively. Serving the roasts immediately resulted in 76.29 per cent servable meat. These differences were highly significant when analyzed for variance. However, no significant differences attributable to animal were found.

Further analysis of the data showed that roasts served immediately and roasts held unsliced had significantly higher ($P \leq 0.01$) amounts of servable meat than roasts held sliced and roasts refrigerated and reheated. Roasts served immediately had a significantly higher ($P \leq 0.05$) amount of servable meat than roasts held unsliced. A highly significant negative correlation coefficient ($r = -0.84$) was found between total losses and servable meat indicating that as total losses increased the amount of servable meat decreased.

Analysis of variance revealed no significant differences due to treatment or to animal for scrap losses. Averages of 10.23, 14.06, 12.67 and 14.11 per cent were obtained for roasts served immediately, roasts held unsliced and sliced and roasts refrigerated and reheated.

The mean number of slices obtained from the roasts for each treatment were approximately the same. Roasts served immediately, roasts held unsliced and sliced and roasts refrigerated and reheated yielded 20, 19, 21 and 20 slices, respectively. However, as already stated, the weight of the slices differed significantly among the four treatments. These results would greatly influence the cost per serving. In order to obtain a uniform 3 oz. portion, slices from roasts held sliced or reheated and refrigerated would have to be thicker than slices from roasts served immediately or held unsliced. For example, roasts served immediately and roasts refrigerated and reheated each yielded an average of 20 slices but the roasts served immediately had 17.43 per cent more servable meat. Thus, the cost of a 3 oz. serving of meat would be higher for roasts refrigerated and reheated than roasts served immediately.

Subjective Evaluation

The quality characteristics of aroma, color of lean, flavor of lean, flavor of fat, juiciness and tenderness were evaluated for each of the four treatments by a panel of seven judges. The intensity of aroma, flavor of lean, and flavor of fat were also evaluated. A 7-point scale was used with a score of one indicating unacceptable quality and a score of seven, excellent quality. Descriptive terms for each score were employed to aid the judges in evaluating the samples.

All judges' scores for each characteristic for each replication were averaged to indicate the quality of the roast. These scores appear in the Appendix, Table 18. Grand means and standard deviations were computed from the averages for each quality characteristic for each treatment (Table 8). Analyses of variance of the quality characteristics of the different treatments are summarized in Table 9. Further differences as noted by Duncan's Multiple Range test (35) are shown in Table 10. Evaluations of intensity of aroma, flavor of lean and flavor of fat were considered as descriptions of the quality characteristics.

Table 8. Grand means and standard deviations for subjective evaluations of quality characteristics of roasts served immediately and held by three methods.

	Holding Method			
	Control	Unsliced	Sliced	Refrigerated and Reheated
Quality Characteristics	1	2	3	4
Aroma	5.4±0.4	5.5±0.5	4.5±0.4	4.5±0.5
Color of lean	6.5±0.3	6.2±0.4	4.8±1.1	3.9±0.7
Flavor of lean	5.8±0.3	5.7±0.4	4.5±0.6	3.9±0.4
Flavor of fat	5.0±0.2	4.8±0.4	3.9±0.6	3.6±0.7
Juiciness	5.4±0.4	5.1±0.3	4.0±0.5	3.4±0.3
Tenderness	5.0±0.5	5.0±0.4	4.1±0.6	4.1±0.3

Table 9. Analyses of variance of subjective evaluation of roasts served immediately and held by three methods.

		Mean Square					
Source of Variance	Degrees of Freedom	Aroma	Color of Lean	Flavor of Lean	Flavor of Fat	Juiciness	Tenderness
Total	23						
Treatment	3	1.919**	8.824**	5.388**	2.575**	5.312**	1.654**
Animal	5	0.215	0.276	0.368	0.371	0.056	0.543**
Error	15	0.145	0.587	0.158	0.211	0.167	0.101

**Significant at the 1 per cent level of probability.

Table 10. Duncan's Multiple Range test[1] for quality characteristics of roasts served immediately (1), held unsliced (2), held sliced (3) and refrigerated and reheated (4).

Quality Characteristics	Significant at $P \leq 0.01$	Additional at $P \leq 0.05$
Aroma	$\underline{1,\ 2} > \underline{3,\ 4}$	
Color of lean	$\underline{1,\ 2} > \underline{3,\ 4}$	
Flavor of lean	$\underline{1,\ 2} > 3 > 4$	
Flavor of fat	$\underline{1,\ 2} > \underline{3,\ 4}$	
Juiciness	$\underline{1,\ 2} > \underline{3,\ 4}$	$3 > 4$
Tenderness	$\underline{1,\ 2} > \underline{3,\ 4}$	

[1]Values underscored by the same line are not significantly different (35).

Aroma

Grand mean scores for aroma quality were 5.4 and 5.5 for the roasts served immediately and roasts held unsliced, respectively, indicating good to very good quality. Opposite results were noted by Funk, Aldrich and Irmiter who found (38) that beef loin roasts held unsliced for 6 and 18 hr. had more aroma than conventionally cooked roasts. However, in their study, the maximum internal temperature of the meat was higher than that of this study. Roasts held sliced and roasts refrigerated and reheated had the same grand mean score of 4.5 indicating an aroma of medium to good quality.

Analysis of variance of the aroma scores revealed highly significant differences attributable to treatment. Further analysis indicated roasts could be held unsliced without significantly affecting the aroma. Therefore, aroma scores for roasts served immediately or held unsliced were significantly higher ($P \leq 0.01$) than those for roasts sliced before holding or reheating. These data suggest aroma components were volatilized from the increased surface area of the sliced meat during the holding or reheating. No significant differences attributable to animal were found.

Aroma intensity grand mean scores were 4.5, 4.7, 4.1 and 4.5 for roasts served immediately, roasts held unsliced, roasts held sliced and roasts refrigerated and reheated, respectively. These values show that aroma was perceptible to slightly pronounced in intensity.

Color of lean

The roasts served immediately and the roasts held unsliced received grand average scores of 6.5 and 6.2, respectively, for color of lean while lower grand average scores of 4.8 and 3.9 were given roasts held sliced and roasts refrigerated and reheated, respectively. Other investigators (38) found conventionally cooked roasts and roasts held unsliced were significantly different in color. The higher scores indicated the meat was light brown shading to pink in the center of the slice. The scores of 4.8 and 3.9 indicated a medium brown color and a gray to light brown color, respectively. Since the meat was sliced in both treatments receiving the lowest scores, more surface area was exposed to heat which would result in color changes in the meat. Judges described most of the samples held by these two treatments as unevenly colored, blotchy, or mottled in appearance. This appearance was probably the result of the overlapping arrangement of the slices in which the top of the slices were more exposed to air and heat. Lyon reported (73) similar results in a study of refrigerated and reheated beef roasts.

Analysis of variance revealed a highly significant difference for color of lean attributable to treatment. The differences among animals were not significant. Further analysis of the data showed the roasts served immediately and the roasts held unsliced scored significantly higher ($P \leq 0.01$) than roasts held sliced and the roasts refrigerated and reheated.

<u>Flavor of lean</u>

Grand mean scores for the quality of flavor of lean were 5.8 and 5.7 for the roasts served immediately and roasts held unsliced, respectively, indicating a good to very good flavor. The roasts held sliced received a grand average score of 4.5 indicating a medium to good flavor while the refrigerated and reheated roasts had a lower score of 3.9 indicating poor to medium quality in flavor of lean. A few of the judges described the flavor of the roasts held sliced as warmed over or almost flavorless. Comments on the flavor of the refrigerated and reheated roasts indicated a strong flavor with an aftertaste.

Analysis of variance computed for flavor of lean scores revealed highly significant differences attributable to treatment but none among animals. Further analysis showed the roasts served immediately and the roasts held unsliced scored significantly higher ($P \leq 0.01$) than the roasts held sliced or the roasts refrigerated and reheated. Also, highly significant differences between roasts held sliced and roasts refrigerated and reheated were found.

The grand mean intensity score for flavor of lean of 5.9 was highest for roasts served immediately while roasts refrigerated and reheated received the lowest grand mean score of 4.7. The roasts held unsliced and sliced received grand mean scores of 5.8 and 5.1, respectively.

The correlation coefficient ($r = 0.92$) obtained between quality of flavor of lean and color of lean scores was highly significant as was the correlation coefficient ($r = 0.83$) for the quality of flavor of lean and aroma scores.

Flavor of fat

Analysis of variance revealed highly significant differences attributable to treatment for scores of the flavor of fat. However, no significant differences were found among animals. Upon further analysis, fat from the roasts served immediately and from the roasts held unsliced was found to be significantly better ($P \leq 0.01$) in flavor than the fat from roasts held sliced and roasts refrigerated and reheated.

Grand mean scores for quality of the flavor of fat were 5.0, 4.8, 3.9 and 3.6 for roasts served immediately, roasts held unsliced, roasts held sliced and roasts refrigerated and reheated. One judge commented that the flavor of fat for the roasts held unsliced was rancid. Comments of the judges for flavor of fat of roasts held sliced and roasts refrigerated and reheated indicated the fat had a rancid or oxidized flavor.

The grand mean score of 5.5 for intensity of fat flavor for roasts served immediately indicated the good quality flavor was slightly to moderately pronounced. When roasts were held unsliced, the grand mean intensity score was 5.1 showing a slightly pronounced medium to good quality fat flavor. The poor to medium flavor of fat scores for roasts held sliced and for roasts refrigerated and reheated were perceptible to slightly pronounced as indicated by the grand mean intensity scores of 4.9 and 5.1, respectively.

A highly significant correlation coefficient ($r = 0.78$) was obtained between the quality of the flavor of fat and aroma scores indicating roasts with good aroma also had fat with good flavor. The correlation coefficient ($r = 0.82$) obtained between flavor of fat and flavor of lean was also highly significant.

<u>Juiciness</u>

Grand mean scores for juiciness were 5.4 and 5.1 for roasts served immediately and roasts held unsliced indicating that the meat was juicy to very juicy. A grand mean score of 4.0 for the roasts held sliced indicated the meat was neither juicy nor dry while the score of 3.4 for roasts refrigerated and reheated indicated the judges rated the sample as slightly dry.

Differences in juiciness scores due to treatments were highly significant. No significant differences were found among animals. Further analysis of the data showed the juiciness scores of roasts served immediately and roasts held unsliced were significantly higher ($P \leq 0.01$) than scores from roasts held sliced and roasts refrigerated and reheated. Also, roasts held sliced were significantly juicier ($P \leq 0.05$) than roasts refrigerated and reheated. Reheating the roasts and holding roasts unsliced was similar to cooking by moist heat since moisture was formed and evaporation kept to minimum by the foil covering the pan. Researchers (32, 58) have shown that the moist heat method results in less juicy meat.

A highly significant correlation coefficient ($r = 0.90$) was found between the quality of flavor of lean and juiciness indicating that flavor components are located in the juice of the meat. This observation is in agreement with that of Kramlich and Pearson (67) who suggested flavor components are located primarily in the juice.

Tenderness

The basis for tenderness scores was the number of chews required to masticate a 1-in. circle of meat. Grand mean scores for roasts served immediately and roasts held unsliced were both 5.0 indicating moderately tender meat. Judges rated roasts held sliced and roasts refrigerated and reheated slightly tough with a grand mean score of 4.1 for both methods. Some of the judges commented that the roasts held unsliced and roasts refrigerated and reheated were slightly stringy or mealy. Chew counts were not always accurate as indicated by panelists' remarks of connective tissue present in the precut meat circles.

Highly significant differences were found in tenderness scores among treatments and among animals. Further analysis revealed that roasts served immediately and roasts held unsliced were significantly more tender ($P \leq 0.01$) than roasts held sliced and roasts refrigerated and reheated. No significant differences were found between tenderness scores of roasts served immediately and roasts held unsliced. Also, tenderness scores from roasts held sliced did not differ significantly from the tenderness scores of roasts refrigerated and reheated. The results of this study do not agree with the suggestion of Bramblett _et al_. (9) that increased cooking or holding between temperatures of 57 and 60°C. was related to an increase in tenderness. Roasts from animals coded 1 and 2 were significantly different from each other in tenderness and from roasts from animals coded 3, 4, 5 and 6. Other researchers have reported (53, 57) significant differences in tenderness among animals.

A highly significant correlation coefficient (r = 0.76) was obtained between tenderness and juiciness scores. A summary of significant correlation coefficients between quality characteristics is found in Table 11.

Table 11. Summary of significant correlation coefficients between subjective evaluation of quality characteristics of roasts served immediately and held by three methods.

Relationship	Correlation Coefficient
Quality of flavor of lean/Aroma quality	0.83**
Quality of flavor of lean/Color of the lean	0.92**
Quality of flavor of fat/Aroma quality	0.78**
Quality of flavor of lean/Quality of flavor of fat	0.82**
Quality of flavor of lean/Juiciness	0.90**
Tenderness/Juiciness	0.76**

**Significant at the 1 per cent level of probability.

Evaluation temperature

Temperature evaluation of each sample was made by the taste panelists using a 3-point scale with a score of 1 indicating Hot; 2, Warm; and 3, Cold. Roasts served immediately and roasts held unsliced received a grand mean score of 1.9 indicating the meat to be warm more than hot. Grand mean scores for roasts held sliced and roasts refrigerated and reheated were 1.8 and 1.6, respectively.

A potentiometer lead was positioned in the center of the slice while in the Dri-Heat assembly to record the serving temperature of the meat. The average temperature recorded was 50°C.

Objective Measurements

Objective measurements of tenderness and juiciness were determined. Tenderness was measured with the Kramer shear-press and juiciness, by the Carver press. Values for the objective measurements for each holding method are summarized in the Appendix, Table 19. Analyses of variance computed for the objective measurements are found in Table 12.

Table 12. Analyses of variance of objective measurements of roasts served immediately and held by three methods.

Source of Variance	Degrees of Freedom	Mean Square: Kramer shear-press: Lb. force/gm.	Mean Square: Kramer shear-press: Area-under-the-curve	Mean Square: Carver Press
Total	23			
Treatment	3	7.528	0.312	65.262**
Animal	5	14.174	0.564	12.169
Error	15	6.151	0.412	7.571

**Significant at the 1 per cent level of probability.

Tenderness

Roasts served immediately had the lowest mean shear-press values, expressed as lb. force/gm., of 16.37, while the

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roasts held unsliced and roasts refrigerated and reheated had similar shear-press values of 17.18 and 17.23, respectively. The roasts held sliced required the largest number of lb. force/gm., 19.03, to shear the sample. The area-under-the-curve values were also determined. Analysis of variance revealed no significant differences attributable to treatment or to animal for shear-press values expressed as maximum force or area-under-the-curve. A significant negative correlation coefficient ($r = -0.41$) was obtained between tenderness scores and shear-press values expressed as maximum force indicating that as the tenderness score increased less force was required to shear the meat. Other investigators (6,10,11,38, 92,98) found significant correlation coefficients between Kramer shear-press values and tenderness scores.

Juiciness

The lowest percentage of press fluid yield was 51.24 for the roasts refrigerated and reheated. The roasts served immediately, roasts held unsliced and sliced had press fluid percentages of 58.55, 57.45 and 54.32, respectively. Differences, attributable to treatment, were highly significant. Further analysis showed roasts served immediately and roasts held unsliced were significantly juicier ($P \leq 0.01$) than roasts refrigerated and reheated. Significant differences ($P \leq 0.05$) were also noted between roasts served immediately and roasts held sliced. No significant differences were noted among animals. Grand mean juiciness scores and mean percentages of press fluid are presented in Table 13. As the percentage of press fluid decreased, the juiciness scores decreased. This relationship would be expected since the held roasts were subjected to heat for a longer period of time and they had the lower juiciness scores. Also, the roasts that were sliced before holding or reheating had more surface area exposed from which the juice could escape. A highly significant correlation (r = 0.67) was obtained between press fluid values and juiciness scores. Other investigators (71,100) have also reported significant correlations between press fluid values and juiciness scores.

Table 13. Means and standard deviations for objective measurements of quality characteristics of roasts served immediately and held by three methods.

Treatment	Kramer shear-press		Carver Press
	Lb. force/gm.	Area-under-the-curve	%
Control	16.37±2.87	3.38±0.88	58.55±1.92
Unsliced	17.18±4.13	2.91±0.60	57.45±2.71
Sliced	19.02±2.13	3.39±0.53	54.32±2.80
Refrigerated and Reheated	17.23±1.69	3.19±0.61	51.24±4.01

Correlation Coefficients between Objective Measurements and Subjective Evaluations

Losses resulting from the four treatments applied to the loin cuts of beef were correlated with subjective evaluations and objective measurements of quality characteristics. The highly significantly negative correlation coefficient ($r = -0.65$) between aroma quality and total losses suggest that components of the meat responsible for high quality aroma decreased as the total losses increased. Total losses were correlated with flavor of lean ($r = -0.90$) and flavor of fat ($r = -0.70$) scores. The highly significant negative correlation coefficients show that flavor of lean and fat decreased in quality as the total losses increased.

Juiciness scores and total losses had a highly significant negative correlation coefficient ($r = -0.92$). The negative correlation coefficient ($r = -0.94$) between juiciness scores and drip losses was also highly significant, indicating that as losses due to drip increased, the meat decreased in juiciness. This relationship is also apparent in the highly significant negative correlation coefficients ($r = -0.72$ and $r = -0.76$) found between total losses/percentages of press fluid and drip losses/percentages of press fluid.

The negative correlation coefficients ($r = -0.66$ and $r = -0.65$) between total losses/tenderness scores and drip losses/tenderness scores suggest the meat samples became less tender as the losses due to treatment were increased.

However, correlation coefficients between total and drip losses and objective measurements were not significant. Significant correlations between losses and subjective evaluation and objective measurements are summarized in Table 14.

Table 14. Summary of the significant correlation coefficients between weight losses and subjective evaluations and objective measurements of roasts served and held by three methods.

Relationship	Correlation Coefficient
Total losses/Aroma quality	-0.65**
Total losses/Flavor of the lean	-0.90**
Total losses/Flavor of the fat	-0.70**
Total losses/Juiciness	-0.92**
Total losses/Percentage of press fluid	-0.72**
Total losses/Tenderness	-0.66**
Drip losses/Juiciness	-0.94**
Drip losses/Percentage of press fluid	-0.76**
Drip losses/Tenderness	-0.65**

**Significant at the 1 per cent level of probability.

Chemical Analyses

The pH values were determined for all raw and cooked meat samples. The thiamine content was determined for four of the six animals used in this study.

pH

The mean pH value for all raw meat was 5.9. Roasts served immediately and roasts refrigerated and reheated had mean values of 5.9 while roasts held unsliced and sliced had mean pH values of 5.8. A comparative analysis of the pH of raw and cooked samples revealed the pH of raw meat and that of cooked meat served immediately differed significantly ($P \leq 0.05$). The pH values for raw and cooked samples for six replications of each treatment are found in the Appendix, Table 20.

Thiamine analysis

Average thiamine content for raw and cooked meat samples was expressed on an as-determined basis. The mean amount of thiamine for the raw roasts was 0.89 mcg. per gram. This value is almost equal to 0.9 mcg. per gram reported by Watt and Merrill (112) for separable lean of the raw beef loin.

For cooked samples, the mean thiamine content was 0.78±0.007, 0.78±0.007, 0.85±0.048 and 0.81±0.017 mcg. per gram for roasts served immediately, roasts held unsliced and sliced and roasts refrigerated and reheated, respectively. Watt and Merrill found (112) that broiled separable beef loin had 0.8 mcg. of thiamine per gram. Thiamine content for the four replications of each treatment are presented in the Appendix, Table 21.

All roasts showed a decrease in thiamine content after cooking and holding. It would be expected that roasts held sliced and roasts refrigerated and reheated would have a lower thiamine content than roasts held unsliced or those served immediately. Perhaps the higher thiamine values of the roasts held sliced or reheated could be explained by the higher total losses for these roasts. The thiamine may be more concentrated in the meat due to loss of juice from the meat.

Evaluation of Holding Methods

In evaluating the three holding methods used in this study, the roasts held unsliced were more acceptable than roasts held sliced or roasts refrigerated and reheated. Subjective evaluation and objective measurements revealed that unsliced roasts were similar to the roasts served immediately in all factors evaluated. The unsliced roasts received the highest subjective rating of the roasts held by the three methods. The amount of servable meat was also the greatest for the unsliced roasts and the total losses were the lowest. Therefore, according to the results of this study, it is recommended, that when feasible in an institutional setting, roasts be held unsliced.

When considering all four treatments, the roast served immediately was judged the most acceptable and was rated the highest in subjective evaluation. Objective measurements proved it to be the most tender and juicy of the four methods. Holding, therefore, should be eliminated as much as possible in a food service operation in order to insure the highest quality of cooked meat.

SUMMARY AND CONCLUSIONS

The primary objective of this study was to compare selected times and temperatures of holding and/or reheating on the palatability characteristics, weight losses and thiamine content of U. S. Choice grade beef loins. Heat transfer during cooking and holding were also examined.

Six pairs of boneless strip loin cuts of beef were halved to obtain the 24 roasts used for the study. After codes were arbitrarily assigned so three of the four cuts from each animal were held by a different method with the fourth cut used as a control, the individual cuts of meat were wrapped, frozen and stored at -23°C. until defrosted for cooking and subsequent evaluation.

Prior to cooking, potentiometer leads were positioned horizontally at three points within each roast to record time-temperature relationships: at the fat, connective tissue-muscle interface; midway between the surface fat and center of the muscle and at the center of the muscle. All roasts were cooked in a 149°C. oven to an internal temperature of 54°C. as recorded by the potentiometer lead positioned in the center of the muscle. After removal from the oven, all roasts were allowed to stand undisturbed at room temperature for 30 min.

The following treatments were then applied. Roasts serving as the control were sliced and served immediately. For the first holding method, unsliced roasts were held 90 min. over dry heat. Roasts held by the second method were sliced and held in the same manner as method one. For the third method, the roasts were refrigerated for approximately 24 hr. and then sliced and reheated to an internal temperature of 60°C. Time-temperature relationships were continuously recorded during holding or reheating.

Percentages of oven cooking, holding, reheating, and slicing losses were obtained for the appropriate treatments. When possible, losses due to drip and evaporation were determined. Percentages of servable meat and scrap were also obtained.

A seven-member taste panel scored all samples for aroma, color of lean, flavor of lean, flavor of fat, juiciness and tenderness. Measurements of press fluid and tenderness using a Kramer shear-press were determined. The pH and thiamine content of raw and cooked samples were determined. The data were analyzed for variance. Appropriate combinations of the data were correlated to determine significant relationships.

An average of 93 min. was required to cook the meat to 54°C. Time-temperature relationships recorded during oven cooking indicated heat penetrated to the center of the muscle tissue at a more rapid rate from the bottom than from the top of the roasts. During the 30-min. period following removal from the oven, the average maximum temperature rose to 60°C.

All roasts cooled slightly during preparation for further treatment. During the 90-min. holding period of the unsliced roasts, the temperature rose from an initial temperature of 55.5°C. to an average of 58°C. Roasts held sliced rose to an average temperature of 59°C. from an initial temperature of 48.5°C. For roasts refrigerated for 24 hr., the average decline in temperature was from 56.5°C. to 4.5°C. which required an average time of 7 hr. and 48 min. During reheating, the rate of temperature rise showed a very slight initial lag followed by a continuous rapid rate of temperature rise over the average 67.2 min. required to heat the sliced meat to 60°C.

Total, drip and volatile cooking losses did not differ significantly among treatments or animals. Total and drip holding losses were significantly higher ($P \leq 0.01$) for roasts held sliced than for roasts held unsliced which in turn were significantly higher ($P \leq 0.01$) than similar losses incurred during refrigerated holding. Volatile holding losses attributable to treatment were not significant. Drip accounted for most of the losses incurred during reheating.

Accumulative total losses were significantly lower ($P \leq 0.05$) for roasts served immediately than similar losses for roasts held unsliced. The accumulative total losses from roasts served immediately and roasts held unsliced were significantly lower ($P \leq 0.01$) than those from roasts held sliced which in turn were significantly lower ($P \leq 0.01$) than similar losses from roasts refrigerated and reheated.

Although the weight of servable meat decreased in order for roasts served immediately, roasts held unsliced, roasts held sliced and roasts refrigerated and reheated, the mean number of slices was approximately the same for all roasts. No significant differences due to treatment or animal were found for scrap loss.

Analyses of subjective evaluations showed roasts served immediately or held unsliced scored significantly higher ($P \leq 0.01$) for aroma quality, color of lean, flavor of fat and juiciness than did roasts held sliced or refrigerated and reheated. Roasts served immediately and roasts held unsliced scored significantly higher ($P \leq 0.01$) in flavor of lean than roasts held sliced and these in turn were significantly higher ($P \leq 0.01$) than similar scores for roasts refrigerated and reheated. Significant differences ($P \leq 0.01$) attributable to treatment and animals were found in tenderness scores. Ranked in order of decreasing tenderness were roasts held unsliced, roasts served immediately, roasts held sliced and roasts refrigerated and reheated.

Roasts served immediately and roasts held unsliced were significantly juicier ($P \leq 0.01$) than roasts refrigerated and reheated as indicated by the percentage of press fluid.

Significant differences were also noted between roasts held sliced and roasts served immediately. No significant differences attributable to treatment or animal were found for Kramer shear-press values expressed as maximum force and area-under-the-curve.

The pH of the raw meat was not significantly different among animals but the pH of the cooked samples varied significantly ($P \leq 0.05$) among treatments. The pH of roasts served immediately decreased during oven cooking. Ranked in order of decreasing thiamine, expressed on an as-determined basis, were the roasts held sliced and roasts refrigerated and reheated followed by roasts served immediately and roasts held unsliced with the same micrograms per gram of thiamine.

Highly significant ($P \leq 0.01$) positive correlation coefficients were found for quality of flavor of lean/aroma quality scores, quality of flavor of lean/color of lean scores, quality of flavor of lean/juiciness scores and tenderness/juiciness scores. Highly significant ($P \leq 0.01$) negative correlation coefficients were found for total losses/flavor of lean scores, total losses/flavor of fat scores, total losses/juiciness scores and total losses/tenderness scores.

From the results of this investigation, the following conclusions were made:

1. To insure the highest quality of cooked meat, roasts should be served immediately,

2. If roasts must be held in an institutional setting, they should be held unsliced to provide the most acceptable product, and
3. Because of poor flavor of the lean and fat as well as high total losses, the method of holding roasts in the refrigerator and then reheating them for service should be avoided.

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APPENDIX

GENERAL INSTRUCTIONS

1. You will be provided with a written schedule of dates and times the taste panel will meet. Meat samples will be served hot.

2. Please do not eat or smoke for 1/2 hour prior to the time of tasting.

3. Please do not give any reactions, such as grimace, smile, or vocal expression, as you evaluate the sample.

4. Please judge the factors of **AROMA, COLOR OF LEAN, FLAVOR OF LEAN, FLAVOR OF FAT, JUICINESS, TENDERNESS AND CHEW COUNT,** and **TEMPERATURE OF SAMPLE** in the order in which they are listed on the score card. The factors of **AROMA, FLAVOR OF LEAN,** and **FLAVOR OF FAT** will be evaluated for intensity as well as quality. Place a check, using a red pencil, in the block which most nearly fits your evaluation of each factor. Be sure to score each of the factors listed on the score sheet. Use descriptive terms when applicable.

5. Score each meat sample independently of others.

* * * * * * * * * * * * *

AROMA. Evaluate aroma on the basis of a sniff obtained immediately after the removal of the plate cover. Consider the intensity of the aroma as well as the quality.

COLOR OF LEAN. Record your overall impression of color as it appears from the exterior to the center of the lean.

FLAVOR OF LEAN. Cut a piece of meat for flavor evaluation one-half inch in from the edge of the lean (use the side of the slice next to the browned fat surface). Consider the intensity of the flavor as well as the quality. Rinse your mouth with the water provided after the flavor evaluation.

FLAVOR OF FAT. Cut a piece of fat for flavor evaluation from the fat with browned surface, including both the browned surface and the interior fat in your sample. Consider the intensity of the flavor as well as the quality. Crackers and/or water may be used to remove traces of fat from your mouth.

JUICINESS. Evaluate the impression of juiciness produced during the first few chews. Cut a piece of meat for juiciness evaluation one-half inch in from the edge of the lean, adjacent to the sample used for the flavor of lean evaluation.

TENDERNESS AND CHEW COUNT. Evaluate the ease of mastication to determine tenderness. Use the pre-cut circle in your sample for your chew count. Count the number of chews required for the circle of meat to disappear from your mouth without conscious swallowing. Record the number of chews in the appropriate block corresponding to the tenderness score you assign the sample.

TEMPERATURE OF SAMPLE. Evaluate your impression of the temperature of the sample when first tasted.

BE SURE TO CHECK THE SCORE CARD WHEN YOU FINISH EACH SAMPLE TO MAKE SURE NO FACTORS HAVE BEEN OMITTED.

BEEF SCORE CARD

Judge______________ Code No.______________ Date__________

FACTOR		7	6	5	4	3	2	1
AROMA	Intensity	Very pronounced	Moderately pronounced	Slightly pronounced	Percept-ible	Moderately percept-ible	Slightly percept-ible	Impercept-ible
	Quality	Excellent	Very good	Good	Medium	Poor	Very poor	Unaccept-able*
COLOR OF LEAN		Light brown to deep pink	Light brown to pink	Medium brown to light pink	Medium brown	Grey to light brown	Grey through-out	Very grey through-out
FLAVOR OF LEAN	Intensity	Very pronounced	Moderately pronounced	Slightly pronounced	Percept-ible	Moderately percept-ible	Slightly percept-ible	Impercept-ible
	Quality	Excellent	Very good	Good	Medium	Poor	Very poor	Unaccept-able*
FLAVOR OF FAT	Intensity	Very pronounced	Moderately pronounced	Slightly pronounced	Percept-ible	Moderately percept-ible	Slightly percept-ible	Impercept-ible
	Quality	Excellent	Very good	Good	Medium	Poor	Very poor	Unaccept-able*
JUICINESS OF LEAN		Extremely juicy	Very juicy	Juicy	Neither juicy nor dry	Dry	Very Dry	Extremely dry
TENDERNESS AND CHEW COUNT		Extremely tender	Very tender	Moderately tender	Slightly tough	Tough	Very tough	Extremely tough

TEMPERATURE OF SAMPLE

Hot ________
Warm ________
Cold ________

*Describe:

Comments:

Table 15. Percentages of total, drip and volatile cooking losses for six replications of roasts served immediately and held by three methods.

Method	Animal (replication)	Cooking Losses Total	Drip	Volatile
Control	1	11.06	3.23	7.83
	2	11.76	5.04	6.72
	3	15.93	5.25	10.68
	4	11.65	3.14	8.51
	5	12.06	3.43	8.63
	6	11.44	3.80	7.64
Average		12.32	3.98	8.34
Unsliced	1	12.06	2.25	9.81
	2	13.62	4.60	9.02
	3	11.87	3.28	8.59
	4	9.12	4.33	4.79
	5	12.11	4.38	7.73
	6	16.09	5.21	10.83
Average		12.48	4.01	8.47
Sliced	1	13.75	5.10	8.65
	2	8.38	2.33	6.05
	3	12.72	4.32	8.40
	4	14.67	4.93	9.74
	5	14.52	5.62	8.90
	6	13.49	4.45	9.04
Average		12.92	4.46	8.46
Refrigerated and Reheated	1	13.80	4.44	9.36
	2	11.81	4.16	7.65
	3	11.33	5.32	6.01
	4	12.51	3.39	9.12
	5	13.46	4.47	8.99
	6	13.71	4.62	9.02
Average		12.77	4.40	8.37

Table 16. Percentages of losses for six replications of roasts served immediately and held by three methods.

Holding Method	Animal (replication)	Holding Losses Total	Holding Losses Drip	Holding Losses Volatile	Slicing Losses	Reheating Losses
Control	1	...	...	...	5.43	...
	2	...	...	...	4.28	...
	3	...	...	...	1.81	...
	4	...	...	...	6.24	...
	5	...	...	...	4.30	...
	6	...	...	...	4.00	...
Average		...	...	...	4.34	...
Unsliced	1	3.80	2.77	1.03	2.72	...
	2	3.44	2.47	0.97	2.09	...
	3	2.69	1.77	0.91	2.85	...
	4	7.89	2.42	5.47	3.64	...
	5	3.21	2.19	1.02	2.70	...
	6	3.04	2.02	1.01	2.27	...
Average		4.01	2.27	1.74	2.68	...
Sliced	1	8.30	7.75	0.55	1.45	...
	2	8.52	8.10	0.42	1.35	...
	3	8.91	8.45	0.46	1.16	...
	4	6.20	5.76	0.44	1.31	...
	5	7.96	7.34	0.62	1.20	...
	6	7.97	7.48	0.49	1.29	...
Average		7.89	7.48	0.50	1.29	...
Refrigerated and Reheated	1	2.05	1.07	0.98	0.49	11.99
	2	1.43	0.48	0.95	0.38	14.91
	3	1.49	0.69	0.89	0.35	10.69
	4	1.83	1.03	0.80	0.42	11.76
	5	1.43	0.63	0.80	0.45	13.19
	6	1.61	0.65	0.96	0.35	11.00
Average		1.64	0.74	0.90	0.41	12.38

Table 17. Percentages of servable meat and scrap for roasts served immediately and held by three methods.

Method	Animal (replication)	Servable Meat	Scrap
Control	1	75.68	12.14
	2	74.06	12.82
	3	71.70	11.49
	4	79.56	7.46
	5	75.07	11.53
	6	81.68	5.92
Average		76.29	10.23
Unsliced	1	73.06	9.76
	2	58.89	22.64
	3	70.30	13.75
	4	67.15	14.92
	5	72.21	11.35
	6	67.67	11.94
Average		68.23	14.06
Sliced	1	55.10	21.40
	2	75.59	6.15
	3	63.14	14.07
	4	63.46	14.38
	5	67.05	9.27
	6	66.47	10.77
Average		65.14	12.67
Refrigerated and Reheated	1	59.00	12.68
	2	58.84	12.62
	3	58.15	18.49
	4	58.39	15.59
	5	58.01	13.15
	6	60.77	12.15
Average		58.86	14.11

Table 18. Average quality characteristic scores of seven judges for six replications of roasts served immediately and held by three methods.

Holding Method	Animal (replication)	Aroma	Color of Lean	Flavor of Lean	Flavor of Fat	Juiciness	Tenderness
Control	1	5.4	6.9	6.1	5.0	5.6	5.7
	2	5.3	6.0	5.7	4.9	4.6	5.0
	3	5.4	6.6	5.6	5.3	5.7	4.6
	4	5.0	6.5	5.3	5.0	5.3	4.5
	5	5.7	6.7	6.1	5.0	5.4	4.9
	6	5.6	6.4	6.0	4.7	5.6	5.3
Grand Average		5.4	6.5	5.8	5.0	5.4	5.0
Unsliced	1	5.1	5.9	5.7	4.7	5.4	5.7
	2	5.5	6.2	5.8	5.2	5.0	5.0
	3	4.9	6.6	5.7	4.4	4.6	4.4
	4	5.4	5.7	4.9	4.6	4.5	4.9
	5	6.1	6.6	6.0	4.3	4.9	5.0
	6	6.1	6.4	6.1	5.4	5.3	4.7
Grand Average		5.5	6.2	5.7	4.8	5.1	5.0
Sliced	1	4.1	4.1	4.0	3.7	3.7	4.7
	2	4.4	7.0	5.6	4.0	4.9	4.7
	3	4.2	4.5	4.2	3.7	3.7	3.5
	4	4.6	3.9	4.4	3.6	3.6	3.7
	5	4.3	4.6	4.0	3.9	3.9	4.3
	6	5.1	4.9	5.0	4.0	4.0	3.4
Grand Average		4.5	4.8	4.5	3.9	4.0	4.1
Refrigerated and Reheated	1	4.3	3.9	3.6	3.7	3.6	4.6
	2	4.6	3.3	3.9	3.3	3.3	4.1
	3	5.3	5.3	4.3	4.5	3.8	4.2
	4	4.1	4.1	3.4	2.6	3.4	3.9
	5	4.1	3.3	3.6	3.6	2.9	3.6
	6	4.7	3.7	4.3	4.1	3.3	4.1
Grand Average		4.5	3.9	3.9	3.6	3.4	4.1

Table 19. Mean percentages of press fluid and shear-press values for six replications of roasts served immediately and held by three methods.

Method	Animal (replication)	Press Fluid	Kramer Shear-Press	
			Lb. force/gm.	Area-under-the-curve sq.cm.
Control	1	59.02	13.05	2.622
	2	60.63	18.24	3.206
	3	57.06	13.63	4.678
	4	55.57	20.73	2.970
	5	58.83	16.35	2.561
	6	60.20	16.23	4.260
Average		58.55	16.37	3.383
Unsliced	1	58.10	14.91	2.726
	2	58.75	13.18	2.256
	3	54.81	15.66	3.571
	4	60.42	16.65	2.953
	5	53.47	17.69	2.300
	6	59.16	25.00	3.632
Average		57.45	17.18	2.906
Sliced	1	53.20	18.05	2.857
	2	49.80	18.64	3.632
	3	53.89	22.41	2.849
	4	56.02	20.37	4.033
	5	58.06	18.47	3.911
	6	54.94	16.21	3.084
Average		54.32	19.03	3.394
Refrigerated and Reheated	1	56.46	18.76	2.657
	2	46.09	17.68	2.814
	3	53.58	16.28	4.181
	4	47.22	15.95	3.458
	5	50.72	15.21	3.449
	6	53.36	19.50	2.605
Average		51.24	17.23	3.194

Table 20. pH values for six replications of roasts served immediately and held by three methods.

Method	Animal (replication)	pH Raw	pH Cooked
Control	1	6.0	5.9
	2	5.7	5.8
	3	5.8	5.8
	4	5.9	6.0
	5	5.7	5.9
	6	5.8	5.9
Average		5.8	5.9
Unsliced	1	5.8	5.9
	2	5.7	5.7
	3	5.9	5.8
	4	5.9	5.8
	5	5.7	5.8
	6	5.7	5.7
Average		5.8	5.8
Sliced	1	5.8	5.9
	2	5.9	5.8
	3	5.8	5.9
	4	5.9	5.9
	5	5.8	5.9
	6	5.6	5.8
Average		5.8	5.9
Refrigerated and Reheated	1	5.9	5.9
	2	5.7	5.8
	3	6.1	5.9
	4	5.8	5.9
	5	5.7	5.9
	6	6.2	5.8
Average		5.9	5.9

Table 21. Thiamine content for four replications of roasts served immediately and held by three methods.

Treatments	Animals (replications)	Thiamine Content (mcg. per gram)
Control	1	0.78
	2	0.78
	3	0.75
	4	0.81
Average		0.78
Unsliced	1	0.80
	2	0.80
	3	0.76
	4	0.76
Average		0.78
Sliced	1	0.76
	2	1.04
	3	0.96
	4	0.65
Average		0.85
Refrigerated and Reheated	1	0.79
	2	0.76
	3	0.91
	4	0.77
Average		0.81