EFFECT OF INTERNAL TEMPERATURE ON WEIGHT LOSSES, COST PER SERVING, AND PALATABILITY OF CHILLED TOP ROUND ROASTS

by

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TABLE OF CONTENTS

INTRODUCTION

The U. S. Department of Commerce in 1952, estimated that approximately 25 percent of the total value of food consumed in the United States was purchased, prepared and served in quantities far larger than those used in the home. The expenditures for food in most institutions average 40 to 50 percent of the total income of the food service. Often the most expensive and the most popular menu item is meat. When poor meat cookery techniques are used in large quantity food preparation, there is an increased shrinkage of the meat with a resultant rise in the meat cost as well as a decrease in the palatability. Meat costs are influenced not only by the quality of the meat as purchased but also by the relationship between the weight of the edible portion and that of the waste of the inedible portion.

Many institutions allocate between 30 to 36 percent of the food budget for the purchase of meat items. The purchase of meat is influenced by (1) the manner in which it is to be cooked, (2) the physical shape in which it is to be served, (3) the proportion of the useable meat or the net yield in relation to the ratio of bone and fat and (4) the final cost based on a comparison of the amount of various other cuts required for the same purpose in relation to price.

Extensive research had been done on many aspects of meat cookery but little information is available in the literature on roasts of the size generally prepared in institution food service (10 to 15 pounds).

This study was undertaken to determine the comparative weight losses, cost per serving and palatability of top round beef roasts cooked to three internal temperatures, all representing well-done roasts. Two grades of beef, U. S. Choice and U. S. Good, were used.

REVIEW OF LITERATURE

Composition of Beef Muscle

According to Lowe (1955) meat cuts are composed of muscle, fat and bone. The muscle is made up of bundles of fibers held together by connective tissue. The main constituents of connective tissue are water, collagenous and elastic fibers. Globules of fat are deposited in the connective tissue around and between the muscle fibers. The proportion of muscle, fat and bone is affected by the age of the animal, the level of nutrition on which the animal was fed and the location in the carcass from which the meat cut was taken.

In 1955, Lowe stated that muscle fibers grow both in diameter and in length during the growing period of the animal but the number of fibers does not increase after birth. Active and inactive muscle fibers were studied by Hiner, et al. (1953). They reported considerable variation in fiber diameter for different muscles and that the size of the fibers was closely associated with the tenderness of the meat. Likewise, Brady (1937) reported that tenderness is dependent on the size of the bundle of fibers; the greater the number of fibers in the bundle, the finer the texture. He stated further that texture is an indication of tenderness of the meat; the finer the texture, the more tender is the meat.

Hiner, et al. (1955) stated that collagenous fibers are soft and flexible with considerable resistance to pull. These fibers when cooked in water can be hydrolyzed to gelatin. Elastic fibers yield readily to a pulling force and will return to their original length when the stress is removed. In contrast to the white collagenous fibers, elastic fibers are yellow in color, and they are not hydrolyzed readily on cooking. In addition, Hiner, et al. (1955) reported that the amount, size and distribution of the elastic fibers are directly related to the tenderness of beef muscle. Elastic fibers are scattered in the connective tissue of a tender cut of meat and are more concentrated in the less tender cuts.

The amount of collagen in the connective tissue will decrease when there is an increase in the amount of fat deposited in the connective tissue (Batterman, et al., 1952). These investigators maintained cows graded U. S. Cutter on a fattening diet for a period of 70 days after which the cows graded U. S. Utility. They reported that the increased fat content of the muscle was highly correlated to tenderness scores. On the other hand, Husaini, et al. (1950) reported poor correlation between tenderness and intramuscular fat in their studies on beef. They suggested that other grading factors had a more important bearing on tenderness. Wierbicki, et al. (1956) agreed with Husaini and co-workers that there was no relationship between intramuscular fat and tenderness scores and stated that marbling is predominantly a sex characteristic.

Post Mortem Changes in Beef Muscle

Beef muscles change after slaughter, stated Lowe (1955). The post mortem changes are brought about by enzymes, by chemical and physical means and by microorganisms. As the meat cools, the fat gets firmer. The changes which occur in the muscle are: (1) shortening and hardening of the muscle, (2) increase in heat production for a period after death, (3) reduction of the glycogen level, (4) increase in lactic acid and a lowering of the pH, (5) increase in soluble inorganic phosphate (6) decrease in ATP, (7) lowering of electrical resistance, (8) changes in elasticity and (9) changes in the microscopic appearance of the fibers.

Bate-Smith (1948) reported that after slaughter there is a decrease in the pH of the muscle which causes the onset of rigor mortis. Wierbicki, et al. (1956) stated that the toughening of the meat associated with the onset of rigor mortis is due to the formation of actomyosin. According to Wierbicki, et al. (1954) there is a gradual softening of the muscle as rigor mortis recedes. In their studies on beef, Husaini, et al. (1950) stated that with 15 day storage post mortem, tenderness increased for all muscles.

Wierbicki, et al. (1956) stated that as the aging time increases, so does the tenderness of the muscle. They reported that tenderness is closely related to the water holding capacity of the meat proteins. In an earlier study (1954), these same investigators summarized the role of connective tissue in relation to post mortem tenderization of the meat. They stated that the changes in the muscle plasma contributed more to increase tenderness during post mortem aging than changes in the connective tissue.

Effects of Cooking on Beef Muscle

Effect of Heat on Muscle Tissue. The Committee on Cooperative Meat Investigations (1942) stated that the objectives in cooking meat were to retain and to enhance flavor, to increase tenderness, if necessary, and to change color. They stated that if tenderness is increased by the cooking process, it was brought about by two reactions; the coagulation of soluble proteins, which may be a toughening process under certain conditions, and the hydrolysis of collagen to gelatin, which is usually a tenderizing process. The toughening or tenderizing effect of these two reactions depends upon the composition of the meat, its pH, the temperature and the rate at which the meat is cooked.

According to Lowe (1955) the color of meat changes gradually from a deep red or pink to a lighter tint and progresses to brown or gray with an increase in the internal temperature of the meat. Howe (1927) stated that coagulation of the muscle proteins begins at approximately 47° C. and is completed when an internal temperature of 70° to 75° C. is reached.

Cooking Temperatures. Lowe (1955) stated that the optimum cooking temperature varied for different methods of cooking, for the various cuts and kinds of meat, the thicknesses of the cut and for the stage of doneness desired. She found that the optimum oven temperature for roasts ranged from 150° to 160° C. When lower oven temperatures were used, the cooking time was longer and the total cooking losses and fuel consumption were greater. When oven temperatures of 175° C. or higher were used, the cooking time was shorter but cooking losses and fuel consumption were proportionately higher than when oven temperatures of 150° to 160° C. were used.

Cover (1937) roasted beef in a low temperature (125° C.) oven and in a high temperature (225° C.) oven. She reported that for well-done roasts (80° C.), slow cooking in an oven heated to 125° C. resulted in a more tender roast than was possible for one from the same location in the carcass which was cooked to the well-done stage in a hot oven (225° C.). Cooking time, in minutes per pound, of meat was decreased with high oven temperatures, stated Cline, et al. (1932), but the saving in time was decidedly offset by the increase in total cooking losses.

Internal Temperature of Roast. Internal temperature is a measure of degree of protein coagulation. The higher the internal temperature of a roast, the greater the degree of coagulation of proteins. Sartorius and Child (1938) pointed out that muscle proteins increasedin density with coagulation, and coagulated muscle proteins decreased the tenderness of the tender cuts of the meat. The investigators stated that the diameter of the muscle fiber decreased with cooking. They stated that a gradual increase in internal temperature caused the semitendinosus muscle to become more tender until an internal temperature of 75° C. was reached. The authors attributed the increase in tenderness to the extent of hydrolysis of the collagenous fibers.

Winegarden, et al. (1952) reported little or no softening of collagenous fibers after 64 minutes of heating in water at 60° C., but when temperatures of 80° C. or higher were used, there was a decided softening of the tissue. They suggested moist heat cookery for less tender cuts of meat should be continued until the internal temperature of the meat was 80° C. or higher.

Thille, et al. (1932) stated that the length of time required for meat to reach the desired internal temperature was dependent on several factors. These factors are the amount of connective tissue in the muscle, the location of the fat on the meat as well as the size and the arrangement of the muscle fibers. These investigators stated that exterior fat speeded the rate of heat penetration while interior fat retarded it. The difference in rate of heat penetration caused by the location of fat was attributed to a change in heat conductivity of the fat as it changed from a solid to a liquid state.

Factors that Affect the Cooking Losses of Meat

In 1955 Lowe stated that the total loss in weight which occurs during the cooking of meat includes dripping and volatile losses. Much of the volatile loss is the evaporation of the water. The dripping losses include fat, water, salt, nitrogenous and non-nitrogenous extractives. Total cooking losses are influenced by the internal temperature to which the meat is cooked. The higher the internal temperature, i.e., the more well-done the meat, the greater the total losses.

Oven Temperature. Lowe (1955) reported that there is a relationship between the loss in weight and the oven temperature used for cooking the meat. When the oven temperature is high, cooking losses are greater than when a low oven temperature is used.

Effect of Cold Storage. Harrison, et al. (1949) reported that roasts from psoas major, longissimus dorsi, semitendinosus and semimembranosus muscles gradually decreased in weight as the storage time was increased. The average weight loss of the roasts stored for 30 days was 12.9 percent. The authors stated that weight loss during cooking decreased slightly as the aging period was increased.

Paul, et al. (1952) found that cooking losses from one inch thick steaks and from three to four inch thick roasts tended to increase with cold storage up to 24 hours. After this period of time, the cooking losses were nearly constant. They used the semitendinosus and biceps femoris muscles from animals graded U. S. Prime, U. S. Good and U. S. Commercial.

Pearson and Miller (1950) stated that the rate of freezing did not measurably alter the total cooking losses. Slow freezing was considered to require 20 hours for the meat to reach a temperature of 20° F. When five hours was needed for the meat to reach 20° F., it was classified as a medium rate of freezing. Fast freezing reduced the temperature of the meat in one hour to

20^{o} F. All freezer-storage, regardless of the rate of freezing, resulted in a marked increase in cooking losses.

Rate of Heat Penetration. Morgan and Nelson (1926) reported that the rate of heat penetration affected the cooking losses of two-rib standing beef roasts. These investigators used copper skewers that were plated with nickel, and found that heat penetration was faster for skewered than for unskewered roasts. Also, the roasts cooked with skewers had less shrinkage, were more juicy and were more tender than the unskewered roasts.

Alexander and Clark (1939) reported that the size and weight as well as the surface area of the roast affected the rate of heat penetration. A heavier roast cooked faster than did the lighter weight roasts. A thick roast with a small surface area required more minutes per pound, than did a thin roast of the same weight with a larger surface area.

Style of Cutting. In their work, Paul, et al. (1950) reported that differences in cooking time and total cooking losses were not significant for bone-in and completely boned cuts of meat. They stated that differences in the cut of meat rather than in the style of cutting determined the total cooking losses from various steaks, roasts and less tender cuts of meat. Chuck roasts had the greatest percentage of cooking losses than either the rump roasts or short ribe of the less tender cuts, cooked by the moist heat method.

Method of Cooking. Cover and Shrode (1955) cooked bottom rounds by roasting and by pot roasting. The average weight losses were remarkably similar, regardless of the method of cooking and the grade of the carcass. This was true even though the cooking time, in minutes per pound, was longer for oven roasts than for pot roasts.

Grade of Meat. Alexander and Clark (1939) studied the shrinkage and cooking time of rib roasts of different grades. The authors reported the amount of shrinkage varied even when roasts of the same grade and cut of meat from the same location in the carcass were cooked by the same method. Roasts of the higher grades had less evaporation loss but the dripping losses were larger regardless of the style of cut and the method of cooking. Alexander and Clark (1939) also stated that the dripping losses were consistent with the amount of fat in the roast.

Factors that Affect the Palatability of Beef

The Effect of Aging on Palatability Factors. Harrison, et al. (1949) stated that there were some changes in the palatability scores with the aging of beef. These investigators noted little variation in the aroma and flavor scores of roasts removed from the carcass and aged one to 20 days. On the other hand, 30 day aged roasts had developed a "musty" or "off" odor. The juiciness factor followed the same trend as the aroma and flavor scores. There was a decline in the juiciness scores with more than 20 days of aging. The scores for tenderness showed the greatest improvement with aging. Harrison, et al. (1949) also noted the greatest increase in tenderness scores occurred during the first 10 days of aging, but tenderness of the individual muscles was not always linearly related to aging.

In 1952, Paul, et al. reported a histological study of beef muscle samples in relation to tenderness at different stages of aging and cooking. They believed that the relaxation of the muscles, which was associated with the passing of rigor mortis during the aging period, contributed to the tenderness of the meat. Microscopic examination of the tissue indicated that during this period of muscle relaxation, cracks began to appear in the muscle fibers, and the fibers became more nearly straight. These changes in the structure of the muscle tissue had a tenderizing effect.

The Effect of the Age of the Animal on Quality of Meat. Barbella, et al. (1939) stated that 30 month old heifers had a more intense flavor of fat than did the steers of the same age. Both steers and heifers had a more intense flavor of fat than did the younger animals.

Barbella, et al. (1939) also reported that breeding and age of the animal were principal factors that influenced the quantity and the quality of the juice extracted from the muscle fibers. The quantity of juice extracted increased quite rapidly with an increase in fatness of the muscle. The age of the animal was more important to the quality of juice extracted from the meat than the amount of fat in the juice.

Hiner and Hankins (1950) stated that as the age of the animals increased, tenderness decreased for each of the muscles studied. There were highly significant differences in the tenderness of the muscles from veal and cow carcasses, but there were no significant differences between veal and beef from 500 pound steer calves. Among samples within the same age group, there was no correlation between the classes of the animals.

Style of Cut of Meat. Child and Esteros (1937) compared the juiciness and flavor of standing rib roasts and rolled rib roasts. They reported a slightly higher press fluid yield from the standing rib roasts. They stated that there was no consistent difference in flavor between standing and rolled rib roasts. Paul, et al. (1950) reported that palatability scores were very similar for bone-in and boneless beef cuts; the differences were too small to be significant.

Location in the Carcass. A study by Hiner and Hankins (1950) showed there were significant differences in the tenderness of various beef muscles depending on their location in the carcass. These investigators rated the muscles in beef carcasses from the least to the most tender as follows: neck and foreshank, round, chuck at the third rib and across humerus bone, eighth rib, shortloin and loin and the tenderloin. Ramsbottom, et al. (1945) reported that tenderness varied from muscle to muscle in the beef carcass and also within the muscle.

Paul and Bratzler (1955) sliced the semimembranosus muscle into one inch steaks. They reported that the first and second steaks from the anterior portion of the muscle were more tender than those from the center portion while the seventh, eighth and ninth steaks from the posterior portion were less tender.

Evaluation of Palatability

Flavor. Crocker (1948) reported that the flavor of raw meat resides mostly in the juice. He believes that the flavor of cooked meat is predominantly odor and he attributes it to the cracking of the amino acid units of the proteins. He elaborated that the odor of the cooked meat is caused by a variety of chemical substances. These presumably are produced by fragmentation such as deamination or decarboxylation of the amino acids simultaneously with some breakdown of the sulfur bearing amino acid cysteine to yield hydrogen sulfide and proprionic acid.

Tenderness. Tenderness is regarded as the most important factor in the palatability of meat, stated the Committee on Cooperative Meat Investigations (1942). According to Mackintosh, et al. (1936) tenderness can be measured objectively by the use of the Warner-Bratzler shearing apparatus. "Shear" is used to indicate the breaking strength of a core of meat as it is registered on the dynamometer of the apparatus. They reported that the coefficient of correlation between the shear on the cooked sample and the palatability committee was significant. When the sample was limited to fed yearling cattle, the coefficient of correlation between the shear on the cooked sample and the palatability committee was -0.986.

Griswold (1955) noted a highly significant correlation between shear force values and tenderness scores assigned by the taste panel. Deatherage and Garnatz (1952) compared the tenderness values of beef muscle obtained by mechanical test and by taste panel test. They reported poor correlation between the taste panel scores and the shear force value in contrast to Mackintosh, et al. (1936) and Griswold (1955). They suggested that shear strength measured by the machine was not the same factor of tenderness as measured by the taste panel but was a variable closely related to tenderness. The authors concluded that the tenderness value assigned by the taste panel was preferred until an improved mechanical device could be perfected.

Juiciness. According to Wilson (1954) in his report to the members of the Reciprocal Meat Conference, juiciness is an important part of the overall palatability of meat. He stated that different investigators have reported varying degrees of correlation between mechanical juiciness values and panel juiciness scores. The contradictory evidence between the objective and subjective scores for juiciness indicated to him that a reliable objective measurement of juiciness was still needed for meat research. He concluded that human perception of juiciness was influenced as much by the composition of the fluid as by the amount. In the discussion which followed Wilson's report, Hall (Wilson, 1954) argued that poor correlation between press fluid yields and taste panel scores did not altogether mean that palatability-juiciness was a single factor. He stated that panel scores for juiciness may be influenced by the amount of free fluid in the meat and also by the flavor and excitation of the saliva secretion in the mouth, whereas the Carver Press measures only the amount of the expressible fluid according to the pressure applied to it.

Gaddis, et al. (1950) reported data for which the percentage of press fluid was not significantly related to scores for quantity of juice. There was a tendency for the percentage of the press fluid to decrease and the scores for quantity of juice to increase when the amount of fat in the fluid extracted increased. When the fat content of the press fluid was two percent or more, these investigators noted little change in the panel scores. These results were explained by the fact that fat added flavor to the meat which resulted in the stimulation of the saliva, and this in turn increased the impression of juiciness, richness and smoothness. Fat coated the mouth and caused a lasting impression of moistness during the chewing process.

The Yield and the Cost of the Cooked Meat

Knostman and Mustard (1928) reported the percentage yield of available meat from the various cuts of yearling beef carcasses. The cuts of meat used in their study were roasts from rib, chuck, cross arm, shoulder, knuckle and sirloin portions of loin and rump. They stated that the upper buttock of the round which had been prepared as Swiss Steaks, yielded the highest percentage of available meat as there was little bone or fat waste. The average number of servings they obtained per pound of raw meat from the various cuts was 2.32.

A comparison of the yield and cost of roasts from clod, top round and rib was undertaken by Vail and O'Neill (1937). The number of servings obtained from a pound of ribs, as purchased, was less than that from the top round. The cost of an average serving weighing 70 grams from the rib roast was about 180 percent greater than a similar serving from either the round or the clod, regardless of the grade of meat used.

Aldrich (1951) studied the effect of the extent of moist heat cookery on beef rounds graded U. S. Choice and U. S. Good. In determining the actual unit cost of the pot roasts, she deducted the edible trim value from the cost of the raw meat used. The total cost of the raw meat for each grade was divided by the total raw weight of the roasts. The cost per pound of the cooked pot roast was determined by dividing the total cost of the uncooked roast by the total cooked weight.

She stated that the 2.5-ounce portion from the U. S. Choice rounds cost \$0.0114 more than for a similar serving from the U. S. Good beef. There was a further increase of \$0.0055, in the 2.5-ounce portion from U. S. Choice pot roasts over that from comparable U. S. Good roasts, when both grades of beef pot roasts were cooked an additional hour after an internal temperature of 90^{o} C. was reached. She concluded that U. S. Good grade beef rounds, prepared by pot roasting, compared favorably with U. S. Choice in eating quality and offered an opportunity for some saving in the purchase cost. There were no significant differences in the total cooking losses between the two grades. The differences in the final edible portion cost were evidently attributable to the differences in the initial unit cost of the uncooked cuts.

In 1948 Brown reported the cooked yields and shrinkage losses of boneless chuck and round roast from U. S. Good steer beef. The paired roasts were cooked to an internal temperature of 79° C. (175° F.) in a 300° F. oven. The number of 2.5-ounce servings obtained from each pound of uncooked meat was calculated from the total weight of the servings from each roast. No significant relationships between the uncooked roast weights and the cooking losses for inside chuck, inside round and outside round roasts were found. There were significant increases in the cooking losses for outside chuck roasts with increases in the uncooked weight.

Brown (1948) stated that slicing losses for inside and outside chuck roasts were more varied than for inside and outside round roasts. The greatest slicing losses occurred in the chuck roasts and the least in the inside round roasts. She suggested that the large amount of interior fat in the chuck roasts may have accounted for the greater slicing loss.

In conclusion, Brown (1948) reported that there were no significant differences in the final number of servings per pound between inside and outside chuck roasts. Round roasts yielded one-half ounce more per pound than did the chuck roasts. She concluded that with the difference in price between chuck and round roasts, chuck roasts cooked to an internal temperature of 79° C. (175° F.), in a 300° F. oven, would be more economical than round roasts even though the sliceable yield was slightly less.

EXPERIMENTAL PROCEDURE

The meat used for this study consisted of 30 trimmed, chilled top round roasts, 15 graded U. S. Choice and 15 U. S. Good. The weight of the roasts ranged from 3,519 grams (7.75 pounds) to 6,181 grams (13.16 pounds). They were cooked to the following internal temperatures: (1) 80° C. (176° F.), (2) 85° C. (185° F.) and (3) 90° C. (194° F.). These temperatures all produce meat cooked to the well-done stage. A balanced incomplete block design suggested by Cochran and Cox (1950) was used as a guide in selecting the internal temperatures to which the roasts were to be cooked. The specific design for this experiment is given in Table 1.

Table 1. Balanced incomplete block design for the experiment.

Cooking period (Block)	U. S. grades and temperatures, °Centigrade					
1	Good	85	Good	90	Choice	80
2	Choice	85	Good	85	Good	90
3	Choice	90	Good	90	Good	80
4	Good	85	Choice	80	Good	80
5	Good	80	Choice	85	Good	90
6	Choice	85	Choice	80	Choice	90
7	Choice	80	Choice	85	Good	80
8	Choice	85	Good	85	Choice	90
9	Choice	90	Good	85	Good	80
10	Choice	80	Good	90	Choice	90

Method of Preparation

The roasts were delivered to the laboratory on the day prior to cooking and delivery weight of each roast was recorded within one hour of receipt. They were rewrapped and stored for approximately 18 hours in a refrigerator at 0° C. On the day of cooking, while the Reed Reel oven was being pre-heated to 300° F. (149° C.), the roasts were weighed and the storage losses were recorded. The combined weight of a shallow pan, rack and a right angle thermometer was recorded. Each roast was placed on the weighed rack in the pan, fat side up, with the thermometer inserted into the thickest portion of the semimembranosus muscle. Plates I and II show the U. S. Choice and U. S. Good roasts at the pre-cooked stage.

The initial internal temperature of each of the three roasts and the oven temperature were recorded at the beginning of the roasting period and at 15 minute intervals thereafter. The calculations for the rate of heat penetration were determined from these data. This interval for reading temperatures was determined during preliminary work when the approximate rate of heat penetration was established. The roasts were removed from the oven when the predetermined internal temperatures were reached.

Data Obtained

Cooking Losses: Total, Volatile and Drip. Two weights of each roast were recorded for volatile losses. The first weight of the roast, pan, rack, thermometer and drippings was recorded immediately after removal of the roast from the oven, and the second weight one hour later. Calculations for volatile loss of each roast during cooking were based on the second weight. The roast was then transferred to a platter and the total cooking losses were determined by weighing the roast on the platter and

EXPLANATION OF PLATE I

U. S. Good top round roasts before cooking to 80°, 85° and 90° C.

PLATE I

EXPLANATION OF PLATE II

U. S. Choice top round roasts before cooking to 80°, 85° and 90° C.

PLATE II

subtracting the weight of the platter. The dripping losses were calculated by subtracting the combined weight of pan, rack, thermometer and drippings from the original combined weight of pan, rack and thermometer.

Palatability Scores. The taste panel was composed of seven members. The judges used a descriptive term and number type of score card (Form I, Appendix) ranging from extremely good, 10 points, to extremely poor, one point, and scored the roasts for aroma, flavor of lean, tenderness and juiciness.

A wedge-shaped piece was cut from the proximal end of the roast to remove the brown crust and to obtain a straight edge. The gravity angle Hobart meat slicer gauge was set at 18 and three slices of roast, each one-eighth of an inch thick, were removed. The semimembranosus muscle section of each slice was divided into three segments. The samples were labelled from A through I.

Each panel member judged one sample from each of the three roasts approximately one and one-half hours after the last roast was removed from the oven. Each testing period, each judge received a sample cut from the same location in the muscle of the roasts for subjective testing. Tenderness scores were given on the basis of the number of chews required to masticate a piece of meat sufficient for swallowing. During preliminary practice sessions, each judge determined her own standard for the relationship between the number of chews required and the tenderness score given.

Shear Force Values. The Warner-Bratzler shearing apparatus was used to obtain an objective measure of the tenderness of the roasts. Three one-inch cores parallel to the fiber axis were removed with a metal cylinder from a three-inch slice of meat cut from the center of the roast. Each core was representative of the three samples previously prepared from the semimembranosus muscle for the palatability panel. Five shear force readings were recorded for each core and later an average value was calculated. Plate III shows the center slice of the roast and the location of the three cores in the semimembranosus muscle used for shear force readings.

Press Fluid Yields. A mechanical test to measure the juiciness of the roasts was applied to the samples from which all fat and gristle had been removed. The meat for this test was taken from the same center section of the roast after the three cores had been removed for the shear force readings. Two press fluid yields were obtained for each roast. The cooked meat was ground in a Universal No. 3 food chopper. A 25 gram sample of the ground meat was packed into a metal cylinder set in a shallow metal plate. The cylinder was lined with two thicknesses of cheese cloth. The sample of meat was placed in the cylinder in three layers with 5.5-centimeter filter paper separating the layers. A leather disc was placed over the packed ground meat and both were pushed to the bottom of the cylinder with a closely fitting metal core. The complete unit was centered on the platform of the Carver Laboratory Press. A total of 16,000 pounds of pressure was applied to the ground meat over a 15 minute period. The following program for the time and pressure increase was

EXPLANATION OF PLATE III

The center slice of the roast and the location of the three cores in semimembranosus muscle used for mechanical determination of tenderness.

PLATE III

observed:

Time in minutes	Pressure in pounds
1.0	5,000
2.0	7,500
3.0	10,000
5.0	10,000
7.5	12,500
10.0	15,000
11.0	16,000
15.0	16,000

The assembled plate, cylinder and core were removed from the platform of the hydraulic press when the pressure was released. The core was removed and any fluid left on the surface of the core was scraped into the plate with a rubber policeman. Next the cylinder was checked for drops of fluid and removed from the plate. All fluid was poured into a centrifuge tube graduated in 0.1-milliliter division, and the plate was carefully scraped clean with a rubber policeman to collect all possible fluid and fat. The tubes of fluid were placed in a refrigerator overnight and readings were taken the next day for the total volume of press fluid, the volume of serum and the volume of fat.

Cost per Serving. Three U. S. Choice and three U. S. Good top round roasts were cooked to 80° C. (176° F.), 85° C. (185° F.) and 90° C. (194° F.) in a 300° F. oven. The roasts were sliced one hour after removal from the oven. This procedure was repeated once to obtain some basis for comparison. The method of cooking and of recording all weights was similar to that described previously. Each slice was divided into two-ounce servings as weighed on a Toledo portion scale, Model No. 1091 A.

The number of servings obtained from the roast was recorded. The cooked weight, number of two-ounce servings, and the cost per pound of the sliceable meat were the information used to calculate the cost per serving of the roasted beef. The cost of the edible scraps obtained during the slicing process of the cooked meat was not deducted from the cost per serving of the two-ounce portions.

Statistical Analysis

The following data were analyzed: (1) the effect of grade and internal temperature of the meat on aroma, flavor, tenderness and juiciness; (2) the effect of the locations in the semimembranosus muscle, from which the three cores were removed to obtain an objective measure of tenderness; (3) the effect of grade and internal temperature of the meat on press fluid yields, cooking time and cooking losses. Correlation coefficients were determined for: (1) shear force values versus tenderness scores, (2) press fluid yields versus juiciness scores, (3) total cooking losses versus juiciness scores, (4) total cooking losses versus press fluid yields, (5) volume of fat in the press fluid versus dripping losses and (6) cooking time versus total cooking losses.

RESULTS AND DISCUSSION

Storage Losses

The roasts were weighed within one hour of receipt, rewrapped and stored in a refrigerator at 0° C. for approximately 18 hours. Then, they were weighed immediately before cooking. The average 18 hour storage losses from the two U. S. grades of top round roasts are shown in Table 2.

Table 2. Average 18 hour storage losses from two U. S. grades of top round roasts.

U. S. Grade	Storage loss g	Storage loss %
Choice	28	0.5
Good	23	0.4

Detailed data are in Table 7, Appendix. Storage losses for U. S. Choice roasts ranged from 0.2 to 2.2 percent and averaged 0.5 percent, whereas those for U. S. Good roasts ranged from 0.3 to 0.8 percent and averaged 0.4 percent.

Cooking Time, Rate of Heat Penetration and Cooking Losses

<u>Cooking Time</u>. The average cooking time, in minutes per pound, for U. S. Choice and U. S. Good roasts cooked to three internal temperatures is shown in Table 3. The average cooking time for U. S. Choice roasts cooked to internal temperatures of 80°, 85° and 90° C. was 30, 35 and 39 minutes per pound, respectively. The average cooking time for U. S. Good roasts

cooked to 80°, 85° and 90° C. was 32, 36 and 44 minutes per pound, respectively.

Table 3. Average cooking time in minutes per pound for U. S. Choice and U. S. Good top round roasts cooked to three internal temperatures.

U. S. Grade	Internal temperature, °Centigrade		
	80	85	90
Choice	30	35	39
Good	32	36	44

There was a very highly significant positive correlation of 0.840 between cooking time, in minutes per pound, and total cooking losses. There were no significant differences in the cooking time attributable to differences in the grade of the meat. However, there were very highly significant differences in cooking time among the roasts cooked to three internal temperatures. There were significant differences between the cooking time of the U. S. Good roasts cooked to 80° C. and those cooked to 85° C., whereas there were only near significant differences between the cooking time of the U. S. Good roasts cooked to 85° C. and those cooked to 90° C.

<u>Rate of Heat Penetration</u>. The average rate of heat penetration for two U. S. grades of top round roasts are shown in Figs. 1 and 2. The average rate of heat penetration for U. S. Choice and U. S. Good roasts cooked to 80°, 85° and 90° C. was three degrees Centigrade in a 15 minute interval. The rate of heat penetration ranged from zero to eight degrees Centigrade in a 15 minute interval.

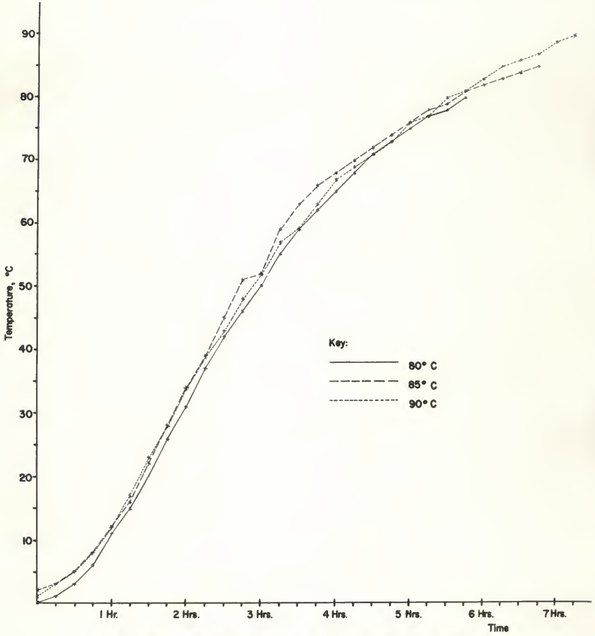


Fig. I. Average rate of heat penetration of U.S. Choice roasts cooked to three internal temperatures.

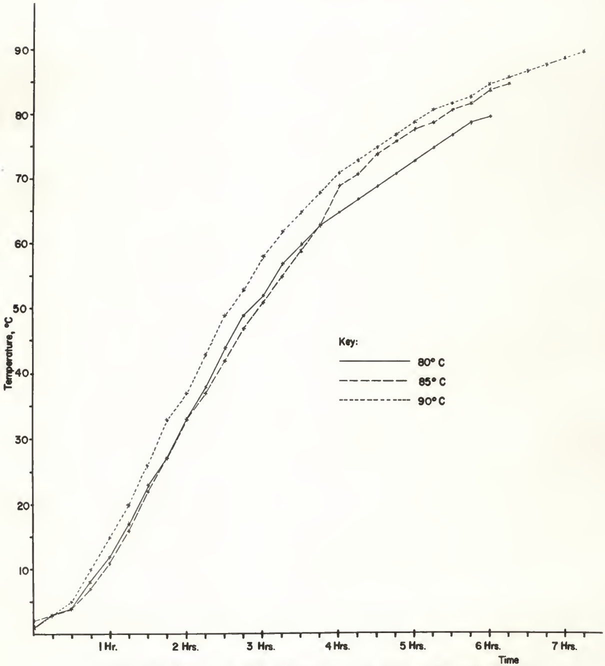


Fig. 2. Average rate of heat penetration of U.S. Good roast cooked to three internal temperatures.

The greatest rate of heat penetration generally occurred when the roasts had been cooking for one and one-half hours. There was a marked decrease in rate of heat penetration during the last hour of cooking.

Cooking Losses. The average cooking losses-total, volatile and drip, from top round roasts graded U. S. Choice and U. S. Good, cooked to three internal temperatures are listed in Table 4. The average percentage total cooking losses for the U. S. Choice roasts cooked to 80°, 85° and 90° C. were 29, 32 and 38 percent, respectively. The average percentage total cooking losses for the U. S. Good roasts cooked to 80°, 85° and 90° C. were 31, 35 and 37 percent, respectively.

The total cooking losses increased as the internal temperature of the roasts increased. Statistical analysis showed that the higher cooking losses for the U. S. Good roasts cooked to 85° C. when compared to those roasts cooked to 90° C. were nearly significant. There were no significant differences in the cooking losses between U. S. Good roasts cooked to 80° C. and those of the same grade cooked to 85° C. The total cooking losses for all U. S. Choice roasts cooked to 80°, 85° and 90° C. were significantly increased with each increase in the end temperature to which the roasts were cooked. There were very highly significant increases in the cooking losses between the roasts cooked to 80° C. and those cooked to 90° C.

The volatile losses, Table 4, were always slightly higher for the roasts graded U. S. Good than for those graded U. S. Choice. There was only a 0.4 percent difference between the

Table 4. Average cooking losses from U. S. Choice and U. S. Good top round roasts cooked to three internal temperatures.

Internal temperature	U. S. Grade	Total cooking losses		Volatile losses		Dripping losses	
		g	%	g	%	g	%
80° C. (176° F.)	Choice	1,475	29	986	19	486	10
	Good	1,637	31	1,152	22	483	9
85° C. (185° F.)	Choice	1,600	32	1,195	24	403	8
	Good	1,885	35	1,373	26	510	9
90° C. (194° F.)	Choice	1,955	38	1,208	28	447	9
	Good	1,666	37	1,290	28	375	8

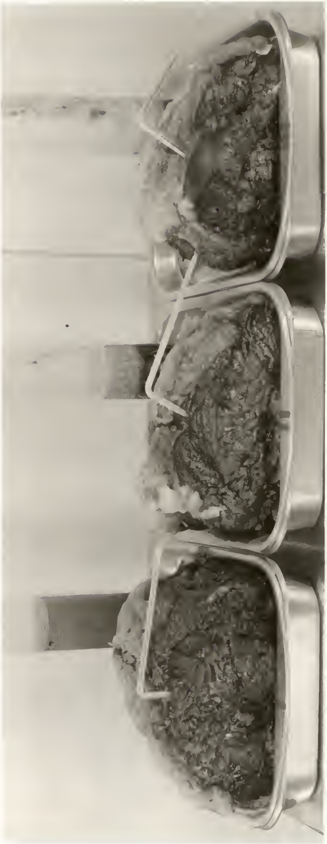
U. S. Good and the U. S. Choice roasts cooked to 90° C. The greatest difference in the average volatile losses, 2.0 percent, occurred between the two grades of top round roasts cooked to an internal temperature of 80° C. The average volatile losses for U. S. Choice roasts cooked to 85° C. was 26 percent and that for the U. S. Good roasts was 24 percent. The average volatile losses (Tables 10 and 11, Appendix) ranged from 19 percent for U. S. Choice roast, internal temperature of 80° C., to 28 percent for U. S. Good roast, internal temperature of 90° C. There were significant increases in the volatile losses of the U. S. Choice roasts cooked to three internal temperatures. The volatile losses of the U. S. Good roasts cooked to 80° C. and the roasts cooked to 85° C. were significantly increased, whereas the U. S. Good roasts cooked to 85° C. and those cooked to 90° C. were not significantly different.

The dripping losses given in Table 4 were similar for the U. S. Choice and U. S. Good roasts. Plates IV and V show the volume of dripping losses from U. S. Good and U. S. Choice roasts cooked to three internal temperatures. The average percentage dripping losses ranged from 8 percent for the U. S. Good roasts, cooked to 90° C. to 9 percent for the roasts cooked to 80° and 85° C. The percentage dripping losses for the U. S. Choice roasts ranged from 8 percent for those cooked to 85° C. to 10 percent for the roasts cooked to 80° C. The U. S. Choice roasts cooked to 90° C. had 9 percent dripping losses. There was a difference of 1 percent between the two U. S. grades of meat cooked to an internal temperature of 80° C. The difference between the U. S. Choice and U. S. Good roasts cooked to 85° C.

EXPLANATION OF PLATE IV

U. S. Good top round roasts after cooking to 80°, 85° and 90° C., and total drippings from each roast.

PLATE IV



EXPLANATION OF PLATE V

U. S. Choice top round roasts after cooking to 80°, 85° and 90° C., and total drippings from each roast.

PLATE V

was 0.5 percent and 0.3 percent for roasts cooked to 90° C. internal temperature. None of these differences in the dripping losses between grades and internal temperatures of the meat were significant.

Aroma and Flavor

Table 5 presents the average palatability scores, shear force values and press fluid yields for U. S. Choice and U. S. Good top round roasts. The highest possible score for each factor was 10 points. The average aroma scores for the two U. S. grades of meat were very similar.

The grade and the internal temperature of the roast did not produce any significant differences in the aroma and flavor scores.

Tenderness

The average tenderness scores are tabulated in Table 5. The average tenderness scores for the U. S. Choice roasts cooked to 80°, 85° and 90° C. were 7, 7 and 8 points, respectively. The average tenderness scores for the U. S. Good roasts cooked to 80°, 85° and 90° C. were 6, 7 and 8 points, respectively.

The effect of temperature on tenderness scores with either Choice or Good grade roasts was linear only. Significant increases in tenderness scores occurred between roasts of Choice and Good grade cooked to 80° C. and those cooked to 90° C. There were no significant differences in the roasts of either grade cooked to 80° C. and those cooked to 85° C. or between

Table 5. Average palatability scores, shear force values and press fluid yields for U. S. Good and U. S. Choice top round roasts.

Internal temperature	U. S. Grade	Aroma*	Flavor*	Tenderness		Juiciness	
				Score*	Shear, lbs	Score*	Press fld. ml/25 g
80° C. (176° F.)	Choice	7	7	7	24.7	6	7
	Good	7	7	6	23.6	6	6
85° C. (185° F.)	Choice	7	7	7	21.8	6	6
	Good	7	7	7	19.3	7	6
90° C. (194° F.)	Choice	7	7	8	20.8	4	6
	Good	7	6	8	16.9	5	6

* Highest possible score, 10 points.

roasts cooked to 85° C. and those cooked to 90° C.

All the average shear force values, pounds required to shear a one-inch core of meat, were lower for the U. S. Good grade roasts than for the U. S. Choice grade roasts. Average shear values for roasts graded U. S. Good were 23.6, 19.3 and 16.9 pounds for roasts cooked to 80°, 85° and 90° C., respectively. Average shear values for U. S. Choice grade roasts were 24.7, 21.8 and 20.8 pounds for roasts cooked to 80°, 85° and 90° C., respectively. The U. S. Choice roasts cooked to an internal temperature of 80° C. required the most force in pounds for shearing.

Statistical analysis showed highly significant differences in shear values attributable to the location of the sample in the semimembranosus muscle from which the three cores for the shear force readings were removed. The cores were labelled A, B and C, shown in Plate VI. There were significant differences between the shear values for cores taken from locations A and B, whereas there were no significant differences between cores removed from locations B and C.

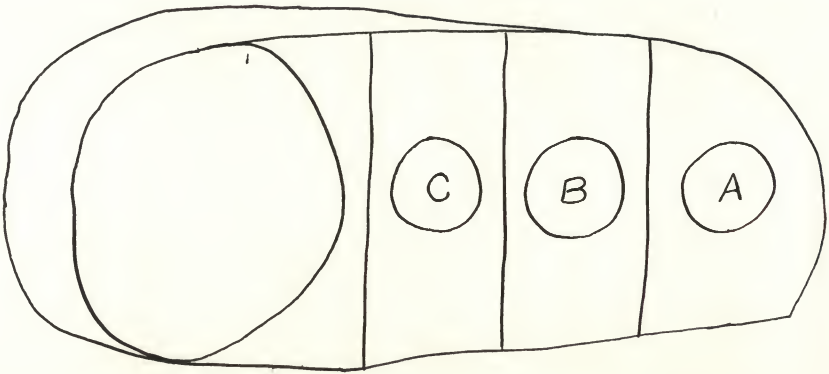
There was a very highly significant negative correlation ($r = -0.567$) between shear force values from location A in the muscle and the average tenderness scores which represented all three sections sampled for shearing tests. In addition, there was a significant negative correlation ($r = -0.443$) between shear force values for location B in the muscle and the tenderness scores, whereas there was a negative, but non-significant correlation ($r = -0.316$) for samples from location C in the muscle

EXPLANATION OF PLATE VI

Semimembranosus muscle

A, B and C represent location of samples for taste panel and for the shear force readings.

PLATE VI



and the tenderness scores.

Juiciness

The average scores for juiciness of U. S. Choice and U. S. Good top round roasts given by the taste panel are shown in Table 5. The U. S. Choice roasts cooked to 80°, 85° and 90° C. had average juiciness scores of 6, 6 and 4 points, respectively. The U. S. Good roasts cooked to 80°, 85° and 90° C. had average juiciness scores of 6, 7 and 5 points, respectively.

The U. S. Good roasts were rated juicier than the U. S. Choice roasts, with the exception of the U. S. Choice roasts cooked to 80° C. However, a greater volume of press fluid was obtained from the U. S. Choice grade roasts with the exception of the press fluid yields from the U. S. Good roasts cooked to 90° C. The average press fluid yields for the U. S. Choice roasts were 7, 6 and 6 milliliters per 25 grams of ground meat for roasts cooked to 80°, 85° and 90° C., respectively. The average press fluid yields from the U. S. Good roasts cooked to 80°, 85° and 90° C. were 6, 6 and 6 milliliters per 25 grams of ground meat.

Significant decreases were noted in the juiciness scores with increases in the internal temperature of the roast. There were no significant decreases in the juiciness scores between the two U. S. grades of meat cooked to 80° C. and those cooked to 85° C., whereas there was a significant decrease in the juiciness scores between all roasts cooked to 85° C. and those cooked to 90° C.

There was a slight but non-significant positive correlation of 0.173 between total press fluid yields and juiciness scores. There was a very highly significant negative correlation coefficient between the total cooking losses and the juiciness scores ($r = -0.602$). The volume of fat in the total press fluid and the dripping losses showed a non-significant positive correlation of 0.018.

Yield and Cost per Serving

Table 6 lists the weight of the roasts, cost of the meat, number of two-ounce servings obtained, weight of the sliced meat and the slicing loss. Six U. S. Choice and six U. S. Good roasts were cooked to 80°, 85° and 90° C. Three U. S. Choice and three U. S. Good roasts were sliced one hour after the roasts were removed from the oven. Three U. S. Choice and three U. S. Good roasts were refrigerated overnight and sliced approximately 18 hours after removal from the oven.

The purchase price per pound of the U. S. Good roasts was $0.69. There was an average increase of 152 percent in the cost per pound of the cooked U. S. Good roasts over the original purchase price. The average cost per pound of the cooked U. S. Good roasts was $1.05. The U. S. Good roasts cooked to 80°, 85° and 90° C. cost an average of $1.02, $1.04 and $1.08 per pound, respectively.

The purchase price per pound of the U. S. Choice roasts was $0.79. There was an average increase of 157 percent in the cost per pound of the cooked U. S. Choice roasts over the original

Table 6. Average cost per serving and slicing loss for U. S. Choice and U. S. Good top round roasts.

Internal temperature	U. S. Grade	Weight of meat				Cost of meat			No. 2-oz serv.	Wt. sliced meat		Slicing loss		
		Raw		Cooked		AP[1]	EP[2]	per serv.						
		#	oz	#	oz					#	oz	#	oz	%
80° C.	Choice	12	15	7	12	$0.79	$1.275	$0.198	53	6	7	1	6	19.1
	Good	12	11	8	9	0.69	1.022	0.159	56	7	1	1	5	17.1
85° C.	Choice	11		7	8	0.79	1.157	0.197	48	5	9	1	13	25.7
	Good	11	15	7	11	0.69	1.042	0.187	46	6	4	1	9	19.5
90° C.	Choice	9	11	6	1	0.79	1.307	0.228	35	4	6	1	11	27.4
	Good	11	12	7	12	0.69	1.083	0.207	39	5	5	1	8	23.3

AP[1] Cost per pound, as purchased.
EP[2] Cost per pound, edible portion.

purchase price. The average cost per pound of the cooked U. S. Choice roasts was \$1.25. The U. S. Choice roasts cooked to 80°, 85° and 90° C. cost an average of \$1.28, \$1.16 and \$1.31 per pound, respectively.

The average weight of the sliced meat obtained from the U. S. Good roasts was six pounds three ounces. There was an average of 47 servings. The number of servings varied from 39 for the roasts cooked to 90°, to 46 servings for the roasts cooked to 85° and 56 servings for the roasts cooked to 80° C.

The average weight of the sliced meat from U. S. Choice roasts was five pounds seven ounces. There was an average of 45 servings. The number of servings varied from 35 for the roasts cooked to 90°, to 48 servings for the roasts cooked to 85° and 53 servings for the roasts cooked to 80° C.

The slicing losses increased as the internal temperature of the roasts was increased from 80°, to 85° to 90° C. The slicing losses for U. S. Choice roasts were 19, 26 and 27 percent, respectively for the roasts cooked to 80°, 85° and 90° C. The slicing losses for the U. S. Good roasts cooked to 80°, 85° and 90° C. were 18, 20 and 23 percent, in the order listed.

The average cost per serving of the U. S. Choice roasts ranged from \$0.198 to \$0.197 to \$0.228 for the roasts cooked to 80°, 85° and 90° C. internal temperature, respectively. The average cost per serving of the U. S. Good roasts was \$0.159, \$0.187 and \$0.207, respectively for the roasts cooked to 80°, 85° and 90° C.

SUMMARY

This study was undertaken to determine the comparative weight losses, cost per serving and palatability of top round beef roasts cooked to three internal temperatures, 80°, 85° and 90° C., all representing well-done roasts.

The meat used for this study consisted of 30 trimmed, chilled top round roasts, 15 graded U. S. Choice and 15 graded U. S. Good. A 300° F. oven temperature was maintained to roast the meat. A balanced incomplete block design was used to select the internal temperatures to which the roasts were cooked.

The average 18 hour storage losses of the inside round roasts from U. S. Choice and U. S. Good were determined. The average storage loss for the U. S. Choice roasts was 0.5 percent and 0.4 percent for the U. S. Good roasts.

Cooking time, in minutes per pound, was calculated for all top round roasts. There were highly significant differences in the cooking time attributable to internal temperature, but there were no significant differences in the cooking time attributable to the grade of the meat.

The total cooking losses increased as the internal temperatures of the roasts increased. Among the U. S. Good roasts there were significant increases in the total cooking losses between 80° and 85° C., but there was no significant increase in the total cooking losses between the roasts cooked to 85° and 90° C. The total cooking losses for all U. S. Choice roasts were significantly increased with each increase in the end temperature

to which the roasts were cooked. There were very highly significant increases in the cooking losses between the roasts cooked to 80° C. and those cooked to 90° C.

There were significant increases in the volatile losses of the U. S. Choice roasts cooked to three internal temperatures. The volatile losses of the U. S. Good roasts cooked to 80° C. and the roasts cooked to 85° C. were significantly increased, whereas the U. S. Good roasts cooked to 85° C. and those cooked to 90° C. were not significantly different.

The grade and the internal temperature to which the meat was cooked did not produce any significant differences in dripping losses, volume of fat in the press fluid and the total press fluids.

The palatability factors for aroma, flavor, tenderness and juiciness were judged by a taste panel of seven members. The highest possible score for each factor was 10 points. The Warner-Bratzler shearing apparatus was used to measure the tenderness of the roasts. An objective measure for juiciness was determined from the press fluid yields with the use of a Carver Laboratory Press.

No significant differences were observed in the aroma and flavor scores attributable to either grade or internal temperature of the meat.

The tenderness scores were significantly increased between all roasts cooked to 80° C. and those cooked to 90° C. There was no significant increase in the tenderness scores between roasts cooked to 80° C. and those cooked to 85° C. or between roasts cooked to 85° C. and those cooked to 90° C.

Statistical analysis showed significant differences in shear values attributable to the location of the sample in the semimembranosus muscle. Significant differences occurred between shear values from locations A and B. There was a slight but non-significant difference between shear values from locations B and C. There was a very highly significant negative correlation of -0.567 between shear force values from location A in the muscle and the average tenderness scores which represented all three locations sampled for shearing tests. In addition, there was a significant negative correlation ($r = -0.443$) between shear force values for location B and the tenderness scores. There was a negative, but non-significant correlation of -0.316 between shear force values for samples from location C in the muscle and tenderness scores.

The U. S. Good roasts were rated juicier than the U. S. Choice roasts, with the exception of the U. S. Choice roasts cooked to 80° C. However, a greater volume of press fluid was obtained from the U. S. Choice than from the U. S. Good roasts, with the exception of the press fluid yields from the U. S. Good roasts cooked to 90° C. There was a slight but non-significant positive correlation between total press fluid yields and the juiciness scores ($r = 0.170$). There was a very highly significant negative correlation of -0.596 between total cooking losses and juiciness scores, and between total cooking losses and press fluid yields ($r = -0.602$). Among those factors significantly affected by temperature changes in the roasts, only the juiciness scores decreased with temperature increases.

The average cost per pound of the cooked U. S. Good roasts was \$1.05, an increase of 152 percent over the purchase price. The average cost per pound of the cooked U. S. Choice roasts was \$1.25, an increase of 157 percent over the purchase price.

The slicing losses from U. S. Choice roasts cooked to 80°, 85° and 90° C. were 19, 26 and 27 percent of the cooked weight of the meat, respectively. The slicing losses from U. S. Good roasts cooked to 80°, 85° and 90° C. were 18, 20 and 25 percent of the cooked weight of the meat, respectively.

The average cost per serving of the U. S. Choice roasts increased from \$0.198 to \$0.197 to \$0.228 and the cost per serving of the U. S. Good roasts increased from \$0.157 to \$0.187 to \$0.207 as the internal temperatures to which the meat was cooked increased.

The internal temperature to which the meat was cooked rather than the grade of meat, determined the quality of the edible portion as measured by palatability. U. S. Good top round roasts compared favorably with U. S. Choice top round roasts in eating quality and offer an opportunity for some savings in the purchase cost of beef roasts for food service institutions.

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APPENDIX

Table 7. Average 18 hour storage losses from two grades of top round roasts.

U. S. Grade	18 hour storage loss grams	18 hour storage loss percent
	117	2.2
	15	0.3
	16	0.3
	20	0.4
	19	0.4
	20	0.4
	10	0.2
Choice	22	0.5
	20	0.4
	28	0.5
	17	0.3
	12	0.2
	31	0.6
	36	0.6
	32	0.7
Average	28	0.5
	26	0.5
	21	0.4
	16	0.3
	30	0.6
	42	0.7
	13	0.3
	43	0.8
Good	22	0.4
	18	0.4
	23	0.4
	18	0.4
	16	0.4
	20	0.4
	14	0.3
	23	0.5
Average	23	0.4

Table 8. Cooking time, in minutes per pound, and weight loss of U. S. Choice roasts.

Internal temperature	Minutes per lb.	Raw wt. g	Raw wt. lbs.	Cooked wt./g	Cooked wt./lbs.	Weight loss g	Weight loss %
80° C. (176° F.)	27	5,095	11.22	3,730	8.21	1,365	25
	30	4,970	10.95	3,544	7.80	1,426	29
	33	4,980	11.19	3,500	7.71	1,480	30
	29	5,622	12.39	4,003	8.81	1,619	29
	29	4,827	10.63	3,343	7.34	1,484	31
Average	30	5,099	11.28	3,624	7.97	1,475	29
85° C. (185° F.)	32	4,668	10.28	3,242	7.14	1,426	31
	42	5,155	11.35	3,339	7.35	1,820	35
	32	4,525	9.97	3,144	6.92	1,381	31
	35	4,452	9.81	3,079	6.78	1,373	31
	36	5,660	12.47	3,672	8.08	1,988	35
Average	35	4,892	10.78	3,295	7.25	1,598	32
90° C. (194° F.)	43	5,264	11.59	3,139	6.91	2,125	41
	36	4,919	10.83	3,088	6.01	1,831	37
	39	5,208	11.47	3,291	7.25	1,917	37
	41	5,742	12.65	3,560	7.84	2,182	38
	37	4,765	10.49	3,045	6.71	1,720	36
Average	39	5,180	11.41	3,225	6.94	1,955	38

Table 9. Cooking time, in minutes per pound, and weight loss of U. S. Good roasts.

Internal temperature	Minutes per lb.	Raw wt. g	Raw wt. lbs.	Cooked wt./g	Cooked wt./lbs.	Weight loss g	Weight loss %
	32	5,106	11.25	3,460	7.62	1,646	32
	32	4,819	10.61	3,339	7.35	1,480	31
80° C. (176° F.)	34	5,032	11.08	3,408	7.51	1,624	32
	29	4,661	10.27	3,393	7.47	1,268	27
	32	6,181	13.61	4,014	8.84	2,167	35
Average	32	5,160	11.36	3,523	7.76	1,637	31
	33	5,214	11.47	3,420	7.53	1,794	34
	38	5,230	11.52	3,432	7.56	1,798	34
85° C. (185° F.)	37	5,369	11.82	3,407	7.51	1,962	36
	34	5,076	11.18	3,444	7.59	1,632	32
	37	5,766	12.70	3,529	7.75	2,237	39
Average	36	5,331	11.74	3,446	7.59	1,885	35
	42	5,092	11.22	3,201	7.05	1,890	37
	47	3,591	7.91	2,241	4.94	1,350	38
90° C. (194° F.)	39	5,216	11.49	3,248	7.13	1,968	38
	39	4,563	10.05	2,886	6.35	1,677	37
	41	4,209	9.28	2,762	6.08	1,447	34
Average	44	4,534	9.99	2,868	6.31	1,666	37

Table 10. Cooking losses: total, volatile and drip for U. S. Choice roasts.

Internal temperature	Total		Volatile		Drip	
	g	%	g	%	g	%
80° C. (176° F.)	1,365	25	841	17	522	10
	1,426	29	942	19	482	10
	1,480	30	1,090	22	389	8
	1,619	29	1,052	19	566	10
	1,484	31	1,006	21	475	10
Average	1,475	29	986	19	486	10
85° C. (185° F.)	1,426	31	1,043	22	382	8
	1,820	35	1,407	27	413	8
	1,381	31	996	22	385	9
	1,373	31	992	22	381	9
	1,988	35	1,535	27	452	8
Average	1,600	32	1,195	24	403	8
90° C. (194° F.)	2,125	41	1,566	30	557	11
	1,831	37	1,390	28	441	9
	1,917	37	1,542	30	376	7
	2,182	38	1,762	31	421	7
	1,720	36	1,279	27	439	9
Average	1,955	38	1,208	28	447	9

Table 11. Cooking losses: total, volatile and drip for U. S. Good roasts.

Internal temperature	Total		Volatile		Drip	
	g	%	g	%	g	%
80° C. (176° F.)	1,646	32	1,186	23	460	9
	1,480	31	1,051	22	424	9
	1,624	32	1,203	24	420	8
	1,268	27	857	18	411	9
	2,167	35	1,463	24	698	11
Average	1,637	31	1,152	22	483	9
85° C. (185° F.)	1,794	34	1,139	22	654	13
	1,798	34	1,317	25	478	9
	1,962	36	1,616	30	345	6
	1,632	32	1,263	25	368	7
	2,237	39	1,531	27	705	12
Average	1,885	35	1,373	26	510	9
90° C. (194° F.)	1,890	37	1,489	29	401	8
	1,350	38	1,080	30	268	7
	1,968	38	1,486	28	482	9
	1,677	37	1,242	27	434	10
	1,447	34	1,154	27	292	7
Average	1,666	37	1,290	28	375	8

Table 12. Average scores for U. S. Choice top round roasts.

Internal temperature	Aroma	Flavor	Tenderness		Juiciness	
			Score	Shear, lbs.	Score	Press fluid ml/25 g
80° C. (176° F.)	6	7	7	28.8	6	7
	7	6	7	24.9	7	7
	8	8	6	33.9	6	7
	7	8	7	17.2	7	8
	8	7	7	18.8	5	7
Average	7	7	7	24.7	6	7
85° C. (185° F.)	7	7	7	15.7	6	7
	7	7	8	20.9	5	6
	8	7	6	24.0	7	5
	7	6	7	25.8	5	8
	7	7	7	23.0	5	5
Average	7	7	7	21.8	6	6
90° C. (194° F.)	7	7	7	23.4	5	4
	7	8	8	22.7	5	6
	8	7	8	24.5	4	7
	7	7	8	16.4	4	6
	7	7	8	17.1	4	6
Average	7	7	8	20.8	4	6

Table 13. Average scores for U. S. Good top round roasts.

Internal temperature	Aroma	Flavor	Tenderness		Juiciness	
			Score	Shear, lbs.	Score	Press fluid ml/25 g
80° C. (176° F.)	7	6	5	18.8	7	7
	6	7	6	20.7	6	6
	6	6	7	21.7	5	6
	7	7	6	40.4	6	6
	7	7	7	16.6	6	6
Average	7	7	6	23.6	6	6
85° C. (185° F.)	7	7	6	21.1	7	5
	7	7	7	19.3	6	7
	8	8	8	18.1	6	6
	6	7	8	23.8	6	7
	8	7	8	14.5	5	4
Average	7	7	7	19.3	7	6
90° C. (194° F.)	8	7	6	23.7	5	6
	7	6	9	9.0	4	6
	8	6	7	24.9	6	7
	7	6	7	16.2	5	5
	7	6	9	11.1	4	7
Average	7	6	8	16.9	5	6

Table 14. Cost per serving, and slicing loss for U. S. Choice and U. S. Good top round roasts.

Internal temperature	U. S. Grade	Weight of meat Raw #	Weight of meat Raw oz	Weight of meat Cooked #	Weight of meat Cooked oz	Cost of meat AP[1]	Cost of meat EP[2]	Cost of meat per serv.	No. 2-oz serv.	Wt. sliced meat #	Wt. sliced meat oz	Slicing loss #	Slicing loss oz	Slicing loss %
80° C.	Choice[3]	12	12	8	9	$0.79	$1.181	$0.168	60	7	5	1	4	12
	Choice[4]	13	0	7	8	0.79	1.369	0.228	45	6	1	2	0	26
	Good[3]	13	4	8	13	0.69	1.015	0.151	59	7	13	1	5	15
	Good[4]	12	11	8	9	0.69	1.029	0.168	52	6	13	1	6	20
85° C.	Choice[3]	11	0	7	13	0.79	1.114	0.172	57	5	15	1	14	24
	Choice[4]	11	0	7	3	0.79	1.200	0.223	39	5	3	1	12	27
	Good[3]	12	8	8	3	0.69	1.045	0.174	50	7	2	1	1	13
	Good[4]	11	15	7	11	0.69	1.039	0.201	41	5	6	2	0	26
90° C.	Choice[3]	10	4	6	1	0.79	1.344	0.233	35	4	6	1	11	28
	Choice[4]	9	10	6	0	0.79	1.268	0.224	34	4	6	1	10	27
	Good[3]	12	9	7	14	0.69	1.097	0.200	42	5	11	2	4	28
	Good[4]	11	7	7	10	0.69	1.069	0.214	37	5	0	1	5	18

AP[1] Cost per pound, as purchased.
EP[2] Cost per pound, edible portion.
Choice[3] Sliced one hour after removal from oven.
Choice[4] Sliced after refrigeration overnight, approximately 18 hours after removal from oven.

FORM I

SCORE CARD FOR MEAT

Judge______________ Sample No.______ Kind _______ Date________

	10	9	8	7	6	5	4	3	2	1	
Aroma	Extremely Good	Very Good	Good	Plus	Medium	Minus	Fair	Poor	Very Poor	Extremely Poor	
Flavor of Lean	Extremely Good	Very Good	Good	Plus	Medium	Minus	Fair	Poor	Very Poor	Extremely Poor	
Tenderness	Extremely Tender	Very Tender	Tender	Plus	Medium	Minus	Fair	Tough	Very Tough	Extremely Tough	
Juiciness	Extremely Juicy	Very Juicy	Juicy	Plus	Medium	Minus	Fair	Dry	Very Dry	Extremely Dry	

Preference:

EFFECT OF INTERNAL TEMPERATURE ON WEIGHT LOSSES, COST PER SERVING, AND PALATABILITY OF CHILLED TOP ROUND ROASTS

by

KAY KAZUKO OHATA

B. S., University of Hawaii, 1944

AN ABSTRACT OF A THESIS

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This study was undertaken to determine the comparative weight losses, cost per serving and palatability of top round roasts cooked to 80°, 85° and 90° C. Thirty trimmed, chilled round roasts, 15 graded U. S. Choice and 15 U. S. Good were used in the experiment.

Procedure

Data were obtained for calculation of cooking losses, cooking time and palatability scores. Mechanical measures of tenderness and juiciness were determined with the Warner-Bratzler shearing apparatus and the Carver Laboratory Press, respectively. The cost per serving of the cooked beef was calculated by dividing the cost of the meat as purchased by the number of two-ounce portions obtained from the cooked meat. The data were analyzed statistically with the exception of the calculations based on cost per serving.

A balanced incomplete block design was used to select the internal temperatures to which the roasts were cooked. A constant oven temperature of 300° F. was maintained during the roasting of the top rounds of beef.

Results

The grade and the internal temperature to which the meat was cooked produced no significant differences in aroma and flavor scores. There were no significant differences in dripping losses, volume of fat in the press fluid and the total press fluid yields attributable to the grade or the internal temperature of the meat.

With either U. S. Choice or U. S. Good roasts, the effect of the internal temperature on cooking time, total and volatile cooking losses, tenderness and juiciness was linear.

There were significant differences ($P < .05$) in the cooking time attributable to the temperature to which the roasts were cooked but there were no significant differences in the cooking time attributable to the grade of the meat. Significant positive correlation ($P < .001$) was obtained between cooking time and the total cooking losses.

The total cooking losses for all U. S. Choice roasts cooked to 80°, 85° and 90° C. were significantly increased ($P < .05$), with each increase in the end temperature to which the roasts were cooked. Among the U. S. Good roasts there were significant increases in the total cooking losses between 80° and 85° C., but there was no significant increase in the total cooking losses between the roasts cooked to 85° and 90° C. There were significant increases ($P < .001$) in the cooking losses between the roasts cooked to 80° C. and those cooked to 90° C.

There were no significant differences in dripping losses attributable to the grade or to the internal temperature of the meat. No correlation was observed between the volume of fat in the press fluid yields and the dripping losses.

There were significant differences ($P < .05$) in the volatile losses of the U. S. Choice roasts cooked to three internal temperatures. The difference in volatile losses of the U. S. Good roasts cooked to 80° and 85° C. were significant ($P < .05$), whereas the volatile losses of the roasts cooked to 85° and 90° C. were not significantly different.

The tenderness scores were significantly different for roasts cooked to 80° and 90° C., whereas there was no significant difference between roasts cooked to 80° and those cooked to 90° C.

Significant ($P < .05$) differences in shear values attributable to the sample in the semimembranosus muscle were indicated. There was a significant negative correlation ($P < .001$) between shear force values from the first location of the muscle and the average tenderness scores, which represented all three sections sampled for shearing tests. In addition, there was a significant negative correlation ($P < .05$) between shear force values for the second location in the muscle and the tenderness scores. There was a negative, but non-significant correlation, between shear force values for samples from the third location in the muscle and the tenderness scores.

The U. S. Good roasts were rated juicier than the U. S. Choice roasts, with the exception of the U. S. Choice roasts cooked to 80° C. However, a greater volume of press fluid was obtained from the U. S. Choice than from U. S. Good roasts with the exception of the press fluid yields from the U. S. Good roasts cooked to 90° C. There was a positive but non-significant correlation ($P < .05$) between total press fluid yields and the juiciness scores. There were significant negative correlations ($P < .001$) between the total cooking losses and the juiciness scores, and between total cooking losses and press fluid yields. Among those factors significantly affected by temperature changes in the roasts, only the juiciness scores decreased with temperature increases.

The average cost per pound of the cooked U. S. Good roasts was \$1.05 and for the U. S. Choice roasts, \$1.25. The slicing losses from U. S. Choice roasts cooked to 80°, 85° and 90° C. were 19, 26 and 27 percent of the cooked weight of the meat, respectively. The slicing losses from U. S. Good roasts cooked to 80°, 85° and 90° C. were 18, 20 and 23 percent of the cooked weight of the meat, respectively.

The average cost per serving of the U. S. Choice roasts increased from \$0.198 to \$0.197 to \$0.228, and the U. S. Good roasts from \$0.159 to \$0.187 to \$0.207 as the internal temperatures to which the meat was cooked, increased.

The internal temperature to which the meat was cooked rather than the grade of meat, determined the quality of the edible portion as measured by palatability. U. S. Good top round roasts compared favorably with U. S. Choice top round roasts in eating quality and offer an opportunity for some saving in the purchase cost of beef roasts for food service institutions.