EFFECT OF GRADE AND INTERNAL TEMPERATURE ON PALATABILITY OF REHEATED ROASTED BEEF

by

JOAN RATCHFORD LYON

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Approved by:

Marjorie M. Hemphill
Major Professor

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INTRODUCTION

Americans are spending increasing amounts of money for foods eaten outside the home. Factors contributing to this trend are mobility of population, distance from home to work, rapid growth of school lunch and industrial feeding programs, and high level of national income.

Food standards and methods of preparation acceptable in the past may not be appropriate for today's consumption patterns. As a result, food service managers are beset by many questions for which they are seeking answers.

Meat accounts for approximately 30% of the institutional food budget. Roast beef is a popular and expensive menu item, and presents problems of preparation and service to both small and large food services. Unpublished data of the Department of Institutional Management at Kansas State University (1962) indicated that the food units contacted used many procedures for cooking and serving beef roasts. Some of these were: roasting all night at low temperatures; cooking at high oven temperatures; braising; using or not using meat thermometers to determine doneness; and preparing the day before use, then portioning, and heating as needed.

The purpose of this investigation was to study the effect of 2 grades (U. S. Good and U. S. Standard) and 3 end point temperatures (66, 70, and 74°C) on cooking losses, cost per serving, and palatability of inside round of beef that is to be roasted, refrigerated, sliced, portioned, heated, and served.

REVIEW OF LITERATURE

Many factors influence palatability of meat. Degrees of consumer enjoyment may be varied according to taste and mores of the individual. Simone _et al_. (1958) declared that meat characteristics contributing to palatability were aligned closely to animal composition, which in turn determined grade and subsequent price.

Composition of Beef Muscle

Meat is composed primarily of skeletal or voluntary muscles used to move the body of an animal at will (Griswold, 1962, p. 109). These muscles are made up of long cross-striated fibers about the diameter of a human hair and held together by connective tissue. The number of fibers does not increase after birth. Griswold (1962, p. 109) described single fibers as extending the full length of a muscle with cross-striations giving the fiber the appearance of a row of coins.

Muscle fiber size is related to tenderness in cooked meat. Fiber diameter, Hiner _et al_. (1953) pointed out, is associated closely with tenderness, the more slender fibers being more tender than thicker fibers. Hiner and Hankins

(1950) reported that as age and maturity of animals increased, tenderness decreased. Griswold (1962, p. 109) mentioned that fiber diameter also increased with age.

Proteins of muscle tissue are composed largely of myosin and actin. Griffee et al. (1960, p. 74, 75) concluded that myosin was found in the greatest quantity, 38%; whereas actin represented about 13% of the total. Actomyosin, an elastic contractile gel, may be interlaced between the coin-like bands. Mechanical action of contraction and relaxation was not understood at this time. A fully relaxed muscle, noted Locker (1960), was more tender than a partly contracted one. This aspect may be important in grading muscle of low connective tissue content.

Application of Heat

Meat may be cooked to enhance flavor, odor and appearance, as well as to sterilize the product for human consumption. Application of heat causes both chemical and physical changes in protein and fat resulting in alteration of color, shape and weight. Some of the areas investigated are rigor mortis, color alteration and protein denaturation.

Rigor Mortis. Rigor mortis, a rigid carcass condition, occurs a few hours after animal slaughter. Chemical changes involved in stiffening of skeletal muscles in rigor were described by Lowe (1955, p. 213) as: (1) decrease of glycogen, (2) increase in lactic acid, (3) lower resistence to an electric current, (4) changes in elasticity, and (5) changes in microscopic appearance of the muscle fibers. Other changes included are: (6) shortening and hardening of muscle, (7) increase in muscle heat, (8) lower pH, (9) increase in soluble inorganic phosphate, and (10) changes in microscopic appearance of 8 muscle fibers. Hornstein and Crow (1960) observed that relaxation of rigor with time produced a more desirable flavor than in fresh beef and postulated that as glycolysis continued the increased lactic acid content enhanced the flavor. About 8 days is needed for beef flavor development (Weir, 1960, p. 215).

Rate of heat penetration in freshly slaughtered beef influenced tenderness. Paul *et al*. (1952) suggested that slow roasting procedures caused a rapid development of rigor which left the meat tough before cooking was completed. Quick heating of thin slices of meat prevented rigor development in freshly slaughtered samples.

Color Alteration. Chemical changes that give roasted meat color were attributed by Bernofsky *et al*. (1959) to reflected alterations of myoglobin as it is affected by heat. Temperature of less than 60°C gave little or no color change; 65 to 70°C gave decreasing pinkness; whereas at 75°C and above, complete loss of pinkness was observed (Weir, 1960, p. 213). Bernofsky *et al*. (1959) reported similar temperatures in relation to color changes.

Oxygen combines with myoglobin to form oxymyoglobin, colored bright red. This color continues to brighten for about 30 min. Meat surfaces dehydrate and darken with continued exposure (Lowe, 1955, p. 210). Pink pigments in proximity to brown pigments during early stages of cooking were claimed by Bernofsky _et al_. (1959) to consist of undenatured oxymyoglobin.

Protein Denaturation. Hunt and Matheson (1958) declared that dehydrated beef muscle fibers were always contractile after reconstitution and these fibers retained approximately half their adenosine triphosphate activity. Results were interpreted as being attributable to stepwise denaturation of actomyosin.

After a period of cold storage, internal temperatures raised by roasting changed muscle protein consistency and made it more tender, depending on amounts of connective tissue present. No change in beef muscle proteins from 20 to 30°C was observed by Hamm and Deatherage (1960). Temperatures between 30 to 40°C resulted in mild denaturation by protein chains unfolding to form new salt and/or hydrogen bonds. During this study, temperatures of 40 to 50°C showed beginnings of strong denaturation which formed new stable cross linkages. Satorius and Child (1938) concluded that meat coagulation remained the same between 58 and 67°C and that muscle fiber shrinkage was completed at 67°C.

Quick cooking of meat to 170°F showed a profound effect on tenderness regardless of connective tissue and fat (Ramsbottom et al., 1945). In this study, coagulation and denaturation of protein together with varying degrees of fiber shrinking and hardening affected tenderness more than did connective tissue and fat.

Weight Loss. Weight loss incurred during cooking may be traced to fat and fluid loss (Lowe, 1955, p. 220). At the time weight losses occur, dimension and volume are altered.

Connective Tissue. According to Griswold (1962, p. 112) heat shortens and thickens connective tissue thereby giving cooked meat a plump appearance because of increased width and decreased length. Muscular mechanical strength and quantity of connective tissue were disclosed by Ramsbottom et al. (1945) to be in direct proportion. Active muscles that have the most strain also have the most connective tissue and are the least tender.

Locker (1960) found that the final state of muscle appeared to depend on tension imposed in the hung carcass, as well as on amount of connective tissue. Ramsbottom and Strandine (1948) asserted that least tender muscles had greater collagen content than tender muscles. Application of heat caused connective tissue to soften, change dimension and show weight loss (Weingarden et al., 1952). As the time-temperature relationship and collagen content increased, degrees of change increased. The same relationships were observed by Machlik and Draudt (1963).

Muscle Protein. During cooking, coagulation of muscle protein fibers depends on time and temperature of cooking. Tuomy *et al.* (1957) proposed that toughening increased as the temperature increased. Temperature controlled the degree of toughness and time had no effect on meat held below 180°F. When meat was held above 180°F tenderness increased to a degree dependent upon both time and temperature. Satorius and Child (1938) pointed out that muscle protein coagulation increased density and decreased tenderness and that muscle fiber diameter was decreased at 67°C after which further changes did not occur.

Fatty Tissue. Fatty tissue may be deposited in varying degrees and areas in each animal. When a muscle containing both fatty and lean tissues is cooked, surface fat melts and penetrates the lean meat, thus increasing the fat content of the lean (Thille *et al.*, 1932). Fatty tissues separated from meat become more tender on cooking claimed Ramsbottom *et al.* (1945).

As external and internal fat deposits are laid down in a beef carcass, Krof and Graf (1959) noted that lean became more firm and tender. External fat affected heat penetration and moisture loss; intramuscular fat affected processes of coagulation and moisture loss (Howe, 1927). Relationship of juiciness to fat content was described by Siemers and Hanning

(1953) who mixed lean beef and fat in various proportions. Short cooking periods with a low temperature high fat ratio yielded more juicy meat than did meat with a low temperature low fat ratio.

Cooking Losses. Total cooking loss of meat includes volatile and dripping losses. Volatile loss is from water evaporation primarily; whereas dripping loss is from a liquid discharge containing water, fat, salts, and nitrogenous and non-nitrogenous extractives (Lowe, 1955, p. 242). For total cooking loss, time-temperature varied according to temperature of cooking medium, degree of doneness, meat surface area, and degree of aging. In cuts of meat with additional fat covering and intermuscular marbling, contended Sleeth *et al*. (1958), fat contributed to increased cooking losses.

Grade. Grade, length of aging period, and relative humidity of aging room affected shrinkage of U. S. Choice and U. S. Good beef sides. Alexander (1930) reported well-fattened beef ribs of high grade had greater dripping losses and lower volatile losses than did lean ribs of lower grades. Among roasts grouped according to grade, Alexander and Clark (1939) noted that those in the top grade usually showed high dripping losses and low evaporation losses, irregardless of cutting style or cooking method. Masuda (1955) discerned no significant difference in volatile losses attributable to grade; differences in dripping losses attributable to grade were significant at 90°C internal temperature. Dripping losses at $90^{o}C$ for U. S. Good and U. S. Choice grades were significantly higher than for U. S. Commercial grade.

No significant difference in cooking losses attributable to type of feed, was indicated in a study by Meyer et al. (1960). Fattened cattle had a higher dripping loss than lean animals reported Nelson et al. (1930). These workers noted that a heavier layer of carcass fat inhibited volatile water loss. A study by Thille et al. (1932) was in agreement with the findings of Nelson et al. (1930).

Cooking losses between grades were not significant when comparisons were made in beef cuts cooked by moist heat versus comparable cuts cooked by dry heat (Hood, 1960). On the other hand, Harrison et al. (1953) observed significantly greater cooking losses for loin and sirloin steaks cooked by dry heat than for those cooked by moist heat.

Internal Temperature. Since cooking losses continue as long as the cooking procedure lasts, losses increase as oven or end point temperature of meat raises. Visser et al. (1960) noted that U. S. Good tender and non tender beef muscles cooked to rare, medium, and well done had significant increases in cooking losses as internal temperature progressed from rare through well done degrees of doneness. Two methods of cooking were used, oven roasting and deep fat immersion.

Total losses were greater at all oven temperatures when higher end point temperatures were reached as observed by Marshall et al. (1960). This was demonstrated by Vail and

O'Neill (1937) when 62 slices were obtained from a rib roast cooked at 141°C, but only 51 slices from a matching roast cooked at 232°C. Time and percentage of total cooking losses increased as rib and eye of round steaks were broiled to higher temperatures, reported Gilpin et al. (1965). Steaks broiled to 140°F lost about 25% of their initial weight; losses increased to 40% when end point temperature raised to 180°F. Final internal temperatures for rib steaks of 140, 160, and 180°F were associated with rare, medium, and well done, but this was not true for eye of round steaks. Eye of round steaks were scored medium at 140°F and well done at 160 and 180°F.

Higher cooking losses for meat cooked at low oven temperatures were observed by Bramblett and Vail (1964) when comparing muscles of beef round cooked to an internal temperature of 149°F at 2 oven temperatures, 155 and 200°F. They concluded that an oven temperature of 155°F increased cooking losses because of longer roasting periods. Griswold (1955) reported similar findings.

Cost per Serving. Cost per serving of meat was influenced by internal temperature, grade, and freezer storage. Garner (1959) determined that as internal temperature increased between 80 and 90°C additional cost per pound was incurred for both U. S. Choice and U. S. Good grades. U. S. Choice grade had higher average cost per pound than U. S. Good. Slicing losses of U. S. Choice and U. S. Good beef roasts increased as internal temperature increased, according to Ohata (1956). Average cost per serving of U. S. Choice grade roasts increased from $0.198 to $0.197 to $0.228, and U. S. Good grade roasts from $0.159 to $0.187 to $0.207 as the end point temperature increased. In Ohata's study, eating quality of U. S. Good beef roasts compared favorably with that of U. S. Choice roasts. Wortham (1962) compared fresh versus frozen U. S. Good top round roasts. A cost increase of $0.01 for each 3 ounce portion of cooked meat was shown for frozen as compared to fresh roasts.

Palatability Factors. Eating quality of meat is dependent on numerous factors. Carcass grade, breed, carcass aging, muscle differences, and method and length of time in cooking are included among factors influencing the acceptability of the finished product. Palatability characteristics usually considered in judging cooked meat are aroma, flavor, appearance, texture, tenderness, and juiciness.

Aroma and Flavor. Although flavor and odor components of meat are not well defined, these qualities, in properly cooked meat are largely responsible for appetite appeal. Good flavor development described by Caul (1957) was (1) first impulse of correct flavor, (2) pleasant mouth sensations, (3) lack of individual unsavory taste, and (4) anticipation of next mouthful.

Weak, blood-like flavor of raw meat, maintained Crocker (1948) was primarily in the juice rather than in the fiber.

The slightly salty taste of raw beef may be attributed to presence of lactic acid, phosphoric acid, sodium chloride, potassium chloride, and other salts. Kramlich and Pearson (1958) found the flavor constituents of raw beef and beef juice fractions to be water soluble.

The meaty flavor developed by cooking, according to Crocker (1948), was presumably brought about by certain chemical changes in fiber, not in the juices. Complex combinations of chemical compounds in small amounts result in the meaty flavor, which is primarily an odor. Kind and intensity of flavor and aroma depend partly on cooking method, length of time and degree of doneness (Weir, 1960, p. 215). Howe and Barbella (1937) attributed flavors of cooked meat to the stimuli given to taste buds by inherent organic and inorganic substances such as water-soluble extractives, lipids, small amounts of carbohydrates, and salts or compounds resulting from these products and the proteins.

Appearance. Because eye appeal may influence food selection, appearance which consists of texture and color is an important characteristic of cooked meat. From a study of factors influencing tenderness and texture of beef, Brady (1937) stated that texture is dependent on size of fiber bundles in muscle, the larger bundles being associated with finer texture because of the greater number of fibers in the bundles.

Tenderness. Consumers universally desire tender meat. The relationship of muscle fiber size, distribution of fat, animal age, and amount of connective tissue content determines tenderness palatability. A study by Hiner and Hankins (1950) showed that as age of the animal increased, tenderness decreased.

Ramsbottom and Strandine (1948) investigated comparative tenderness of samples from 8 muscles of U. S. Good grade beef and observed no relationship between amount of fat within the muscle and shear force results for raw or cooked samples. They emphasized that amounts of collagenous and elastic connective tissue in the muscle influenced tenderness of cooked muscles. Tenderness of connective tissue in braised bottom round steaks and loin steaks was studied by Cover (1959). This study pointed out that connective tissue in bottom round was made tender by braising to an internal temperature of 100°C and holding there for 25 min. Loin connective tissue was so tender that no significant effect was obtained from this method of cookery.

Juiciness. Juiciness enhances quality and, therefore, affects acceptability of cooked meat. Lowe (1955, p. 200) stated that intermuscular and intramuscular fat influences juiciness. During cooking, fat becomes liquid and renders out of adipose tissue along with water.

Tenderness and juiciness are closely related; tender meat appears to release juice from the tissue quickly by chewing;

however intermingling fat stimulated saliva flow producing even more moisture in the mouth (Weir, 1960, p. 216). A highly significant effect between fatness and quality of juice was reported by Barbella _et al_. (1939). Solids in solution were found to influence richness of juice along with amount of intermingling fat. Ritchey and Hostetler (1964) declared that meat cooked to high temperatures was less juicy than that cooked to low temperatures. Weir (1960, p. 216) concluded that juiciness varied inversely with cooking losses.

Effect of Oxidative Rancidity on Flavor. Among numerous types of food deterioration, oxidation spoilage has been important. Most commonly recognized as oxidative rancidity, this type of food spoilage is characterized by objectionable odors and flavors.

Harrow (1950) attributed unpleasant odor and flavor of fats to chemical changes in unsaturated fatty acids. The changes involved atmospheric oxygen attacking the double bond which then was catalyzed by moisture, heat, and light.

Cooked meat flavor changes rapidly during room temperature, refrigerated, or frozen storage. Watts (1954) described rancidity as resulting oxidative deterioration of unsaturated fats. High palatability ratings of freshly cooked meats deteriorated rapidly with the passage of time according to Tims and Watts (1958). After a few hours of refrigerated storage, oxidative rancidity tests showed that flavor loss paralleled an increase in thiobarbituric acid values.

Rancidity occurred in cooked beef, chicken, veal and lamb samples tested within a few hours after cooking ceased. Comparable increases in thiobarbituric acid values were not observed in raw meat samples.

Chang et al. (1961) followed oxidation of lipids in lean tissue of roast beef slices preserved by refrigeration, frozen storage, and irradiation. The thiobarbituric acid test and organoleptic evaluations were used. Oxidized products accumulated very quickly in the refrigerator. Frozen samples maintained a slower oxidation rate over long storage periods. Lipid oxidation was not an important factor in irradiated beef stored at room temperature. Oxidation of tissue lipids proceeded at a rapid rate when roast beef was sliced and exposed to air in the refrigerator or at room temperature.

Rancidity development in ground beef muscle was measured using the thiobarbituric acid test by Robertson (1962) through 8 days refrigerated storage. Cooked and raw meat samples were compared while stored under equal conditions. Raw samples developed rancidity significantly faster than cooked samples through the fifth day of refrigeration. Cooked samples showed a significantly higher thiobarbituric acid value initially than raw samples and continued on an elevated level through 8 days of refrigerated storage. Higher initial thiobarbituric acid value in cooked meat was attributed to heat since heat is one factor which triggers development of rancidity.

EXPERIMENTAL PROCEDURE

Design of Experiment

Meat used for this study consisted of 15 U. S. Good and 15 U. S. Standard chilled top round beef roasts procured as needed from a local wholesale distributor. Purchasing procedures available to food services in the area were used; therefore the history of animals involved was not known. Weight at delivery ranged from 16 pounds 13 ounces (7607 grams) to 9 pounds 13 ounces (4482 grams) for U. S. Good roasts and from 15 pounds 8 ounces (7205 grams) to 12 pounds 6 ounces (5602 grams) for U. S. Standard roasts. Average weight for U. S. Good cuts was 13 pounds 6 ounces and for U. S. Standard cuts 13 pounds 14 ounces.

Five roasts of each grade were cooked in a rotary hearth electric oven preheated to 300°F to each of the following internal end point temperatures: 66, 70 and 74°C. These temperatures were selected because a previous study (Thomsen, 1959) indicated that U. S. Choice and U. S. Good roasts cooked to an internal temperature of 65°C had the lowest cooking losses, greatest yield, and highest palatability scores when compared to the same grades cooked to internal temperatures of 70 and 75°C. Beck (1962) investigated the effect of grade (U. S. Good and U. S. Standard) and institutional cut (loin butt, loin tip, loin point, and top round) on cooking losses, palatability, slicing yield, and cost per serving of beef roast cooked to an internal temperature of 65°C. When these experimental roasts were used in campus food service, certain complaints were made. Portions of meat from roasts cooked to 65°C were pink in color. Application of heat produced a mottled grey to brown appearance judged unpalatable. Also, heat sometimes toughened meat previously scored tender.

Ten cooking periods were used; three roasts were cooked during each period. A balanced incomplete block design suggested by Cochran and Cox (1950) was used as a guide in selecting the internal end point temperature to which roasts were to be cooked (Table 1).

Table 1. Experimental design

Cooking period	U. S. grades and temperatures, °C		
	I[a]	II[a]	III[a]
1	Standard 66	Good 70	Good 74
2	Standard 66	Standard 70	Good 66
3	Standard 66	Standard 74	Good 70
4	Good 70	Good 74	Good 66
5	Standard 66	Standard 74	Good 66
6	Standard 70	Good 70	Good 66
7	Standard 66	Standard 70	Good 74
8	Standard 70	Standard 74	Good 74
9	Standard 70	Standard 74	Good 70
10	Standard 74	Good 74	Good 66

[a]Identification numbers assigned to roast at each roasting period.

Roasting

Roasts were delivered to the laboratory early on the day of roasting. Shallow aluminum roasting pans were marked with an identifying number (I, II, or III) to indicate treatment (U. S. grade and internal temperature).

While the electric rotary hearth oven was being preheated to 300°F, roasts were weighed and placed on the appropriately numbered pan. Combined weight of pan, rack, aluminum foil strips, and right angle Centigrade thermometer was recorded. Each roast was placed fat side up on the rack in the pan. The thermometer was inserted into the thickest portion of the semimembranosus muscle. Aluminum foil strips were put between meat and top edge of the pan to keep drip from spilling over edge of the pan into the oven.

Prior to placing each roast in the oven, its initial internal temperature was registered. Temperatures were noted each hour for the first two hours, then at 30 min. intervals or until 60°C was reached. From that point, temperatures were recorded every 5 min. until the predetermined end point temperature was attained. When roasts were removed from the oven, temperatures were taken every 5 min. until the maximum post oven temperature had been reached for each roast and the temperature had dropped 2 degrees. Throughout the procedure appropriate weights of roasts and equipment were taken in order to determine volatile, dripping, and total cooking losses.

Storage

After cooking loss data were obtained, roasts were transferred to pre-weighed trays and covered with aluminum foil pressed tightly over all four edges of the tray. The roasts were stored in a walk-in refrigerator (35°F) for approximately 17 hr. until the following morning.

Slicing

Overnight refrigerated storage losses were determined. Hard outer fat covering was trimmed from roasts prior to slicing. A Hobart gravity food slicer, Model 1512, was used for slicing. Dial positions 10, 12, and 15 controlled slices of proper thickness for the 3 oz. portion size. Serving weights were checked on a Pelouze, Junior Portion-Controller scale. Each serving consisted of 1 to 2 pieces of meat. A double thickness of meat taken from the center of each roast and comprising 2 servings was used for palatability tests. This slice was cut into one half inch cubes. Total weight and number of servings per roast were recorded.

Fat and connective tissue trimmings from each roast were weighed and recorded as non-usable scrap. All small pieces of lean meat, as well as lean ends of each roast were weighed and recorded as usable scrap. Unmeasurable amounts of lean meat, non-usable scrap, and juices that remained on the slicer were calculated in total volatile loss.

Observations of Color

Color and appearance of the heated beef slices were observed when the aluminum foil was removed and pans of sliced 3-oz. roast portions were placed in a heated electric serving cart, as well as after 15 and 30 min. holding intervals. Appearance alteration for each roast was noted. Organoleptic panel members were asked to comment on these two factors on rating sheets.

Reheating

A stainless steel counter pan, 10 by 12 by 2 in., was used as a heating container for each portioned roast. Twelve overlapping servings of beef were positioned to fill half the pan. Taste cubes were placed between servings 12 and 13. Remaining slices were overlapped until a total of 25 portions filled the pan. One third cup, strained, undiluted dripping was poured over the meat and an aluminum foil cover was sealed around pan edges. This procedure was repeated for each roast. The 3 pans of roast beef were heated for 30 min. in a gas reel oven, preheated to 350°F. At the end of this time the pans were transferred to a Blickman food cart, preheated for 2 hr. on dial number 10. Upon inserting pans in the heated food cart, aluminum foil covers used in oven were removed.

Palatability evaluations of meat cubes occurred in a period ranging from 5 to 30 min. after placing meat in the hot cart.

Palatability Test

A panel composed of 11 members of an undergraduate quantity food class, 8 women and 3 men, and 1 graduate woman, were used to evaluate the following palatability factors: serving temperature, aroma, flavor, juiciness, and tenderness. One training session was held to explain the project, procedures for tasting, and the rating sheet to be used. Each panel member was given a printed sheet of instructions (Appendix). Judges used a numerically descriptive score card (Form 1, Appendix).

Each panel member received 2 meat cubes from each roast to evaluate. Two tenderness scores were given; one for initial impression of tenderness and one based on number of chews required to swallow a cube of meat. The amount of mastication needed for a specific tenderness score given was determined by each judge during the preliminary practice session.

Calculation of Cost

At the time of this study, "as purchased" cost per pound of top round beef roast from the local wholesale distributor was U. S. Good, $0.85 and U. S. Standard, $0.79. Cost per pound "edible portion" was calculated by adding weight of total number of servings and edible scrap and dividing into the "as purchased" total cost per roast. Three oz. of meat containing not more than 2 pieces made one serving. Cost per serving was determined by dividing the cost per pound "edible portion" by the servings per pound "edible portion."

Statistical Analyses

Data were subjected to analysis of variance to determine the effect of grade and internal temperature of the roast on dripping, volatile, and total cooking losses; total cooking time; cooking time in min. per pound; and the palatability factors: serving temperature, aroma, flavor, juiciness, initial tenderness, and chew tenderness. Where appropriate, least significant differences were run on the data.

Correlation coefficients were determined for total cooking losses and juiciness, initial tenderness, and chew tenderness; initial tenderness and chew tenderness; and aroma and flavor.

RESULTS AND DISCUSSION

Cooking Time

Total Time. Neither grade nor internal temperature affected total cooking time significantly (Table 2). Average total cooking times for both U. S. grades were lowest for roasts cooked to 66°C and greatest for those cooked to 74°C. U. S. Good roasts cooked to 66°C required less total cooking time than did U. S. Standard roasts cooked to the same temperature. However, U. S. Standard roasts cooked to 70 and 74°C required less total cooking time than did U. S. Good roasts. These differences might be attributed to differences in average weights of roasts. Detailed data are given in Table 11, Appendix.

Table 2. Total cooking time for U. S. Good and U. S. Standard roasts cooked to 66, 70, and 74°C.

Grade		Internal temperature, °C	
	66	70	74
Good	282 min.	310 min.	405 min.
	278	295	271
	294	292	304
	265	289	339
	290	330	313
Avg.	282	303	326
Standard	270	307	288
	274	269	330
	313	315	285
	260	305	300
	345	300	368
Avg.	292	299	314

Minutes per Pound. Significant differences were not found for average cooking time in min. per pound between U. S. Good and U. S. Standard top round roasts, nor among roasts cooked to three internal temperatures (Table 3). For both grades, average cooking times were similar for internal temperatures of 66 and 70°C. At 74°C internal temperature, U. S. Good roasts required 2.6 min. per pound longer than did U. S. Standard roasts, even though U. S. Standard roasts averaged 13 lb. 14 oz. per roast, whereas U. S. Good roasts were 13 lb. 6 oz. per roast.

Table 3. Average cooking time in min. per pound for 2 U. S. grades cooked to 3 internal temperatures.

Grade	Internal temperature, °C		
	66	70	74
Good	21.4	21.8	24.6
Standard	20.9	22.3	22.0

Internal Temperature Rise of Roasts After Removal from Oven

After removal from oven, the internal temperature of each roast was recorded at 5 min. intervals until it had dropped 1°C below the highest reading. A slight rise in temperature was noted for all except 1 U. S. Good and 2 U. S. Standard roasts. The exceptions were 1 U. S. Good roast cooked to 70°C and 2 U. S. Standard roasts cooked to 74°C. Temperature changes recorded during this period ranged from 3.3°C for 2 roasts, one of each grade, to -1°C for 1 U. S. Standard roast. For both grades, all roasts cooked to 66°C increased in temperature. In general, this was true for roasts cooked to 70 and 74°C. At 70°C 1 U. S. Good roast, and at 74°C 2 U. S. Standard roasts decreased in temperature (Table 14, Appendix). Greatest rise of internal temperature was for roasts removed from the oven at 66°C, and least rise for those removed at 74°C (Table 4). Lowe (1955, p. 241) reported that beyond 75°C, little or no rise in temperature occurs.

Average temperature rise for U. S. Good roasts cooked to 66, 70, and 74°C was 2.3, 1.5 and 1.1°C, respectively. For U. S. Standard roasts an average internal temperature increase was shown of 2.2°C at 66°C and 1.1°C at 70°C. However, roasts cooked to 74°C averaged a slight temperature decrease (Table 4).

Table 4. Average maximum temperature rise (°C) of two U. S. grades of top round roasts after removal from oven.

Grade	Internal temperature, °C		
	66	70	74
Good	2.3	1.5	1.1
Standard	2.2	1.1	-0.3

Average time required for maximum temperature rise after removal from oven for U. S. Good roasts cooked to 66, 70, and 74°C are given in Table 5. U. S. Good roasts demonstrated a 2 min. decrease in time as the temperature increased at each level. U. S. Standard roasts showed the widest range with a 20 min. interval between 66 and 70°C and no time differential between 70 and 74°C.

Table 5. Average time (min.) required for two U. S. grades of top round roasts to reach maximum internal temperature rise after removal from oven.

Grade	Internal temperature, °C		
	66	70	74
Good	70	68	66
Standard	78	58	58

Cooking Losses

Average cooking losses, total, volatile, and dripping, from U. S. Good and U. S. Standard grade top round roasts are given in Table 6. Grade did not affect cooking losses significantly.

Table 6. Average total cooking losses for 2 U. S. grades top round roasts cooked to 3 internal temperatures.

Grade	Internal temperature, °C	Cooking losses					
		Total		Volatile		Drip	
		g	%	g	%	g	%
Good	66	1385	23.1	846	14.1	535	9.0
	70	1565	24.4*	886	14.0	675	10.4
	74	1799	29.5	1048	17.4	709	11.4
Standard	66	1570	25.0	761	12.0	786	12.4
	70	1652	27.1*	957	15.7	691	11.3
	74	2006	30.6	1221	18.5	772	11.9
l.s.d.			4.6		-		-

*Significant at the 5% level.

<u>Total</u>. Average total cooking losses for U. S. Good roasts cooked to internal temperatures of 66, 70, and 74°C were 23.1, 24.4, and 29.5%, respectively; whereas those for U. S. Standard roasts were 25.0, 27.1, and 30.6%. At each internal temperature U. S. Good roasts had a lower percentage total cooking loss than U. S. Standard roasts (Table 6). As internal temperatures increased, total cooking losses increased for both U. S. grades of beef. Statistical analysis showed a significant difference in total cooking losses

between U. S. Good roasts cooked to internal temperatures of 66 and 74°C, between those cooked to 70 and 74°C, but not between those cooked to 66 and 70°C. For U. S. Standard roasts, a significant difference was apparent only between roasts cooked to internal temperatures of 66 and 74°C.

Volatile. Significant differences were not found for average volatile losses for roasts of either grade cooked to any of the three internal end point temperatures (Table 6). Average volatile losses for U. S. Good roasts cooked to 66, 70, and 74°C were 14.1, 14.0, and 17.4%, respectively; whereas those for U. S. Standard roasts cooked to 66, 70, and 74°C were 12.0, 15.7, and 18.5%. Volatile losses appeared to be somewhat lower for U. S. Good roasts than for U. S. Standard roasts. However, average volatile losses were lowest for both grades for U. S. Standard roasts cooked to internal temperatures of 66°C and highest for both grades for U. S. Standard roasts cooked to 74°C.

Dripping. Average dripping losses for U. S. Good roasts cooked to 66, 70, and 74°C given in Table 6 were 9.0, 10.4, and 11.4%, respectively; whereas those for U. S. Standard roasts cooked to 66, 70, and 74°C were 12.4, 11.3, and 11.9%. Significant differences for average dripping losses were not apparent for any of the roasts cooked to the three internal temperatures. The greatest difference in average dripping losses between grades was at the 66°C level, U. S. Standard roasts having a 3.4% higher dripping loss than did U. S.

Good roasts cooked to the same internal temperature. At internal temperatures of 74°C, both U. S. grades had similar average dripping losses. U. S. Good roasts lost the least average amount of drippings at 66°C; whereas the reverse was true for U. S. Standard roasts which lost the most at that internal temperature.

Storage Losses of Refrigerated Roasted Beef

Average storage losses of cooked meat placed in a walk-in refrigerator and held at 35°F for approximately 17 hr. are listed in Table 7. U. S. Good roasts cooked to 66, 70, and 74°C lost an average of 108.4, 110, and 108.8 g, or 2.4, 2.4, and 2.6%; whereas U. S. Standard roasts cooked to the same temperatures recorded average losses of 77.8, 78.0, and 95.6 g, or 1.6, 1.8, and 2.2%, respectively. In general, U. S. Good roasts had higher average storage losses at each internal temperature than did U. S. Standard roasts.

Table 7. Average percentage storage losses of cooked meat refrigerated approximately 17 hours.

Grade	Internal temperature, °C					
	66		70		74	
	g	%	g	%	g	%
Good	108.4	2.4	110	2.4	108.8	2.6
Standard	77.8	1.6	78	1.8	95.6	2.2

Slicing Yield

Weight of meat, percentage portion yield, and number of 3 oz. portions may be found in Table 8. Fifteen U. S. Good roasts and 15 U. S. Standard roasts, 5 of each grade were cooked to internal temperatures of 66, 70, and 74°C. After cooking, each roast was refrigerated for approximately 17 hr. and then sliced and portioned into 3 oz. servings. Significant differences resulting from U. S. grade or internal temperature were not found for percentage portion yield which decreased as the internal temperature increased. U. S. Good roasts cooked to 66, 70, and 74°C gave average 3 oz. portion yields of 58.8, 58.2, and 56.3%, respectively; whereas U. S. Standard roasts cooked to 66, 70, and 74°C showed 59.1, 57.6, and 55.3% average portion yields. U. S. Good roasts cooked to 66°C had the highest average portion yield, 58.8%; whereas U. S. Standard roasts showed 56.3% average portion yield at the same temperature. Yield for both grades was lowest for roasts cooked to an internal temperature of 74°C.

Average number of 3 oz. portions for U. S. Good roasts cooked to 66, 70, and 74°C was 42, 44, and 40; whereas U. S. Standard roasts cooked to the same temperatures yielded 45, 43, and 42 servings (Table 8).

Table 8. Average yield and cost per serving for 2 U. S. grades cooked to 3 internal temperatures.

Internal temperature, °C	U. S. grade	Weight of meat: A. P.[1] lb	A. P.[1] oz	E. P.[2] lb	E. P.[2] oz	3 oz portion lb	3 oz portion oz	Usable scrap lb	Usable scrap oz	Portion yield %	Number 3-oz portions	Cost of meat: A. P.[1] per lb	E. P.[2] per lb	per serving
66	Good	13	3	9	11	8	5	1	6	58.8	42	$0.85	$1.25	$0.27
	Std.	14	0	9	11	8	5	1	6	59.1	45	0.79	1.21	0.25
70	Good	14	0	9	5	8	2	1	3	58.2	44	$0.85	$1.32	$0.26
	Std.	13	8	8	14	7	12	1	2	57.6	43	0.79	1.19	0.25
74	Good	13	6	8	8	7	8	1	0	56.3	40	$0.85	$1.32	$0.26
	Std.	14	6	9	4	7	15	1	5	55.3	42	0.79	1.24	0.23

A. P.[1] As purchased

E. P.[2] Edible portion; weight of 3-oz portions and usable scrap

Cost

Throughout this study, the price per pound for U. S. Good roasts was \$0.85 and for U. S. Standard, \$0.79. The edible portion of the roasts consisted of the weight of the 3 oz. portions and the edible scrap. Price per pound for the edible portion was \$1.25 for U. S. Good roasts cooked to 66°C and \$1.32 for those cooked to 70 and 74°C. Roasts, U. S. Standard grade, cooked to 66, 70, and 74°C showed costs of \$1.21, \$1.19, and \$1.24 per pound edible portion, respectively (Table 8).

U. S. Good roasts cooked to 66°C averaged \$0.27 per serving whereas roasts cooked to 70 and 74°C averaged \$0.26 per serving. U. S. Standard roasts cooked to 66 and 70°C cost \$0.25 per serving and those cooked to 74°C averaged \$0.23 per serving. Average range of cost per serving varied \$0.01 for U. S. Good roasts. U. S. Standard cost per serving average range varied \$0.02. Detailed data on costing of all roasts are listed in Tables 17 and 18, Appendix.

Palatability of Reheated Roasted Beef

Appearance. Observations relating to appearance of the heated cooked meat were made by the investigator at time of slicing roasts, removal of aluminum foil cover from pan after heating, and at 15 and 30 min. intervals after placing heated meat in the electric cart. Judges were encouraged to write comments for this factor during the palatability test period.

When sliced, the majority of roasts of both grades were the gray-tan color of well done beef irrespective of internal end point temperature. The exceptions were 3 roasts from U. S. Good grade cooked to 66, 70, and 74°C and 1 roast from U. S. Standard grade cooked to 70°C.

In general, heated slices of beef of both U. S. Good and U. S. Standard grade remained moist in appearance for approximately 30 min. in the electric cart. After that period, rapid deterioration was observable. Edges of the slices dried, curled, and darkened in color. Speckling became evident on exposed surfaces. Some leaching of color was apparent on portions of meat submerged in broth, as a color shift from gray-tan to silvery gray took place. This latter characteristic was more pronounced for slices from U. S. Standard roasts than for those from U. S. Good roasts, and internal end point temperature did not appear to be a factor. Slices from two U. S. Standard roasts also gave evidence of a greenish fluoresence during the 30 min. holding period in the heated cart.

Temperature of Serving Portion. To measure warmth of serving portion at time of eating, a rating scale ranging from 5 to 1 was used. Average scores for serving temperature of heated portions from cooked roasts are listed in Table 9. Significant differences in scores attributable to grade or internal end point temperature were not found. Serving portions from U. S. Good roasts cooked to 66, 70, and 74°C received average temperature of serving scores of 1.9, 1.7,

Table 9. Average values for palatability factors for roasts from 2 U. S. grades cooked to 3 internal temperatures, refrigerated, portioned, and reheated.

Grade	Internal temperature °C	Aroma[1]	Flavor[1]	Juiciness[2]	Tenderness		Serving temperature[3]
					Initial[2]	Chew[2]	
Good	66	2.1	2.1	5.1	5.3	5.3	1.9
	70	1.9	1.8	4.9	5.4	5.4	1.8
	74	2.1	1.9	4.5	5.3	5.5	1.8
Standard	66	1.9	2.0	4.8	4.9	5.0	1.9
	70	2.2	2.1	4.6	4.9	4.8	1.7
	74	2.1	2.1	4.6	4.7	5.0	1.8
Sig. of F values		ns	ns	ns	ns	ns	ns

[1]Maximum score possible, 3

[2]Maximum score possible, 7

[3]Maximum score possible, 5

and 1.8, and those from U. S. Standard roasts cooked to the same temperature 1.9, 1.7, and 1.8, respectively. These scores were all approximately 2 or lukewarm. Rapid cooling of tasting cube was accounted for by morsel size and room temperature china serving plates.

Aroma and Flavor. A rating scale of 3 to 1 was used to measure both aroma and flavor. Three denoted aroma or flavor of freshly cooked beef; 2 indicated an area of neutrality, neither freshly cooked nor "left-over" in aroma or flavor; and 1 signified a "reheated" aroma or flavor (Form 1, Appendix). Statistical analysis showed no significant differences for average mean scores for either aroma or flavor that could be attributed to U. S. grade or internal end point temperature (Table 9). Average mean scores for heated U. S. Good cooked roast portions were similar to those for U. S. Standard cooked roast portions. All average scores were close to 2 which indicated that judges rated them as neutral in flavor and aroma (Table 9). A negative nonsignificant correlation coefficient was obtained for the relationship of aroma and flavor (Table 10).

Tenderness. Two tests for tenderness were used; tenderness based on initial impression and tenderness based on chew count. Tenderness may be considered to consist of three components; ease with which teeth sink into meat when chewing begins, ease with which meat breaks into fragments, and amount of residue remaining after chewing. For palatability rating purposes, initial tenderness was related to the first two factors and chew tenderness to the last factor and number of chews required to bring the meat to the point at which it could be swallowed.

Both initial impression of tenderness and tenderness based on chew count were rated on a 7 point scale (Form 1, Appendix). Significant differences were not found for either initial impression of tenderness or chew tenderness that could be ascribed to U. S. grade or end point temperature used (Table 9). Samples from U. S. Good grade roasts showed slightly higher average scores for both initial tenderness and chew tenderness than did those from U. S. Standard grade. Average mean initial tenderness scores for cubes from U. S. Good roasts cooked to 66, 70, and 74°C were 5.3, 5.4, and 5.3, respectively and chew tenderness scores were 5.3, 5.4, and 5.5, respectively, indicating moderately tender meat. U. S. Standard roasts cooked to the same temperatures produced cubes giving average scores of 4.9, 4.9, and 4.7 for initial tenderness and 5.0, 4.8, and 5.0 for chew tenderness (Table 9). Although these scores were slightly lower than those for U. S. Good roast samples, they were closer to moderately tender than to slightly tough.

Initial impression of tenderness and tenderness based on chew count gave a significant and high positive correlation (Table 10). This finding indicates that initial tenderness could be used as a test for the palatability factor of tenderness rather than chew tenderness, or vice versa.

Initial tenderness scores were affected significantly by total cooking losses. A significant, but only moderately strong, negative correlation was found for these two factors (Table 9). As cooking losses increased, initial tenderness scores decreased indicating some toughening of the meat. When the relationship of chew tenderness to total cooking losses was examined, a nonsignificant negative correlation existed (Table 10).

Table 10. Correlation coefficients for selected paired factors.

Factors	r	Significance
Aroma and flavor	-.0226	ns
Initial tenderness and chew tenderness	.8378	*
Total cooking losses and initial tenderness	-.3796	*
Total cooking losses and chew tenderness	-.1050	ns
Total cooking losses and juiciness	-.5538	*

* Significant at the 5% level (29D/F, r=.36)

ns Nonsignificant

<u>Juiciness</u>. Juiciness was evaluated on a 7 point rating scale (Form 1, Appendix). Juiciness scores for U. S. Good

and U. S. Standard roasts cooked to 66, 70, and 74°C may be found in Tables 19 and 20, Appendix.

Only U. S. Good roasts cooked to 66°C had moderately juicy scores with an average score of 5.1 (Table 9). Juiciness scores for U. S. Good roasts cooked to 70 and 74°C were 4.9 and 4.5, respectively; whereas U. S. Standard roasts cooked to the same temperature were 4.8, 4.6, and 4.6. Both grades roasted to 66°C had slightly higher juiciness scores than those roasted to 70 and 74°C. As the internal temperature increased juiciness scores decreased.

A significant, but only moderately strong, correlation coefficient for total cooking losses and juiciness scores (Table 10) was established. As the total cooking losses increased, juiciness decreased.

SUMMARY

Fifteen U. S. Good and 15 U. S. Standard inside round beef roasts were used to study the effect of grade and internal temperature on cooking losses, slicing yield, cost per 3-oz. serving, and palatability of inside round beef that was roasted, refrigerated, portioned, reheated, and served. The data were analyzed by an analysis of variance for a balanced incomplete block design.

Five roasts of each grade were cooked in a rotary hearth electric oven preheated to 300°F to 3 internal temperatures, 66, 70, and 74°C. Internal temperature rise of the roast was

registered hourly for 2 hours, then at 30 min. intervals to 60°C, and finally every 5 min. to an assigned end point temperature. Volatile, dripping, and total cooking losses; post cooking storage losses; slicing yield; and cost per 3-oz. serving were determined. Twenty-five servings of each roast were reheated for 30 min. in a gas reel oven preheated to 350°F and placed in an electric hot cart. Palatability scores were obtained.

Significant differences attributable to grade or internal temperature were not found for total cooking time, cooking time in min. per pound, dripping loss, volatile loss, and palatability scores. Internal temperature affected average total cooking losses significantly.

A slight rise in post cooking temperature was noted for all but 3 roasts. At each internal temperature, U. S. Good roasts had a slightly lower average total cooking loss than U. S. Standard roasts. In general, average post cooking storage losses were higher for U. S. Good roasts at each internal end point temperature than for U. S. Standard roasts. Average percentage portion yield decreased as internal temperature increased for both grades of beef. U. S. Good roasts had higher average cost per pound and cost per 3-oz. serving than U. S. Standard roasts.

Palatability factors considered for the reheated servings of roasted beef were appearance, temperature of serving, aroma, flavor, initial tenderness, chew tenderness, and juiciness. Heated slices of beef of both U. S. Good and U. S. Standard grade remained moist in appearance for approximately 30 min. before rapid deterioration was observable. Average scores for serving temperature of heated portions from cooked roasts were the equivalent of lukewarm.

Judges rated flavor and aroma as neutral. A negative nonsignificant correlation coefficient was obtained for the relationship of aroma and flavor. Initial impression of tenderness and tenderness based on chew count gave a significantly positive correlation. Initial tenderness scores and total cooking losses showed a significant negative correlation. As cooking losses increased, initial tenderness scores decreased or greater toughening of the meat. Tenderness based on chews and total cooking losses were also negatively correlated although not significantly so.

As the internal temperature increased, juiciness scores decreased. A significant negative correlation coefficient for total cooking losses and average juiciness scores existed.

CONCLUSIONS

Under the conditions of this study, the following statements may be made:

1. U. S. Good and U. S. Standard top round beef roasts cooked to an internal temperature of 66°C had the lowest total cooking losses, as compared to roasts of both grades cooked to 70 and 74°C.

2. U. S. Good and U. S. Standard top round beef roasts cooked to an internal temperature of 66°C had slightly higher average juiciness scores than roasts cooked to 70 and 74°C.
3. U. S. Standard roasts cooked to 3 internal temperatures had lower average post cooking losses than U. S. Good roasts.
4. In general, U. S. Good and U. S. Standard reheated beef serving portions remained moist in appearance after approximately 30 min. in an electric cart.
5. Initial impression of tenderness may be used as a test for palatability factor of tenderness rather than chew tenderness, or vice versa.

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REFERENCES CITED

Alexander, L. M. 1930. Shrinkage of roast beef in relation to fat content and cooking temperature. J. Home Econ. 22, 915.

______ and N. G. Clark. 1939. Shrinkage and cooking time of rib roasts of beef of different grades as influenced by style of cutting and method of roasting. U. S. Dept. Agr. Technol. Bull. No. 676.

Barbella, N. G., B. Tanner, and T. G. Johnson. 1939. Relationships of flavor and juiciness to beef to fattness and other factors. Proc. Am. Soc. Animal Production 32, 320.

Beck, J. 1962. Effect of grade and institutional cut on cooking losses, palatability, slicing yield, and cost per serving of roast beef. Unpublished study, Kansas State University, Manhattan, Kansas.

Bernofsky, C. J., J. B. Fox, Jr., and B. S. Schweigert. 1959. Biochemistry of myoglobin. VII. The effect of cooking on myoglobin in beef muscle. Food Research 24, 339.

Brady, D. E. 1937. A study of the factors influencing tenderness and texture of beef. Proc. Am. Soc. Animal Production 30, 246.

Bramblett, V. D. and G. E. Vail. 1964. Further studies on the qualities of beef as affected by cooking at very low temperatures for long periods. Food Technol. 18, 123.

Caul, J. F. 1957. The profile method of flavor analysis. Advances in Food Research 7, 1.

Chang, P., M. T. Younathan, and B. M. Watts. 1961. Lipid oxidation in pre-cooked beef preserved by refrigeration, freezing, and irradiation. Food Technol. 15, 168.

Cover, S. 1959. Scoring for three components of tenderness to characterize differences among beef steaks. Food Research 24, 564.

Crocker, E. C. 1948. Flavor of meat. Food Research 13, 179.

Department of Institutional Management. 1963. Methods of utilizing low grade beef cuts for pre-cooked portion products. Unpublished study, Kansas State University, Manhattan, Kansas.

Garner, M. E. 1959. Effect of grade and internal temperature on palatability and cooking losses of top round roasts cooked in a gas fired institutional roast oven. Unpublished M. S. thesis, Kansas State University.

Gilpin, G. L., O. M. Batcher, and P. A. Deary. 1965. Influence of marbling and final internal temperature on quality characteristics of broiled rib and eye of round steaks. Food Technol. 19, 834.

Griffee, J. W., M. C. Urbin,J.B. Fox, W. A. Landmann, A. J. Siedler, and R. A. Sliwinski. 1960. Chemistry of animal tissues. In: The Science of Meat and Meat Products, W. H. Freeman and Company, San Francisco.

Griswold, R. M. 1955. The effect of different methods of cooking beef round of commercial and prime grades. I. Palatability and shear values. Food Research 20, 160.

________. 1962. The experimental study of foods. Houghton Mifflin Company, Boston.

Hamm, R. and F. E. Deatherage. 1960. Changes in hydration, solubility and changes of muscle proteins during heating of meat. Food Research 25, 587.

Harrow, B. 1950. Textbook of biochemistry. W. B. Saunders Company, Philadelphia.

Harrison, D. L., G. E. Vail, J. L. Hall, and D. L. Mackintosh. 1953. Household cooking methods for commercial grade beef. Unpublished study, Kansas State University, Manhattan, Kansas.

Hiner, R. L. and O. G. Hankins. 1950. The tenderness of beef in relation to different muscles and age in the animal. J. Animal Sci. 9, 347.

________, O. G. Hankins, H. S. Sloan, C. R. Fellers, and E. E. Anderson. 1953. Fiber diameter in relation to tenderness of beef muscle. Food Research 18, 364.

Hood, M. P. 1960. Effect of cooking method and grade on beef roasts. J. Am. Dietet. Assoc. 37, 363.

Hornstein, I. and P. F. Crowe. 1960. Flavor studies on beef and pork. J. Agr. Food Chem. 8, 494.

Howe, P. E. 1927. The relation of cooking to the study of the quality and palatability of meat. J. Home Econ. 19, 8.

_______ and N. G. Barbella. 1937. The flavor of meat and meat products. Food Research 2, 197.

Hunt, S. M. V. and N. A. Matheson. 1958. The effect of dehydration on actomyosin in fish and beef muscle. Food Technol. 12, 410.

Kramlich, W. E. and A. M. Pearson. 1958. Some preliminary studies on meat flavor. Food Research 23, 567.

Krof, D. H. and R. L. Graf. 1959. Interrelationships of subjective, chemical, and sensory evaluations of beef quality. Food Technol. 13, 492.

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

Lowe, B. 1955. Experimental cookery from the chemical and physical standpoint. 4th ed. John Wiley and Sons, Inc., New York.

Machlik, S. M. and H. N. Draudt. 1963. The effect of heating time and temperature on the shear of beef semitendinosus muscle. J. of Food Sci. 28, 711.

Marshall, N., L. Wood, and M. B. Patton. 1960. Cooking choice grade, top round beef roasts - effect of internal temperature on yield and cooking time. J. Am. Dietet. Assoc. 36, 341.

Masuda, G. M. 1955. Tender cuts of three grades of beef: effect of extent of cooking on weight losses and cost. Unpublished M. S. thesis, Michigan State College, East Lansing, Michigan.

Meyer, B., J. Thomas, R. Buckley, and J. W. Cole. 1960. The quality of grain finished and grass finished beef as affected by ripening. Food Technol. 14, 4.

Nelson, P. M., B. Lowe, and M. D. Helser. 1930. Influence of the animal's age upon the quality and palatability of beef. Part II. The roast beef, preparation, quality, and palatability. Iowa Agr. Exptl. Sta. Bull. 272.

Ohata, K. K. 1956. Effect of internal temperature on weight losses, cost per serving, and palatability of chilled top round roasts. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas.

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

Ramsbottom, J. M. and E. J. Strandine. 1948. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Research 13, 315.

________, E. J. Strandine, and C. H. Koonz. 1945. Comparative tenderness of representative beef muscles. Food Research 10, 497.

Ritchey, S. J. and R. L. Hostettler. 1964. Relationships of free and bound water to subjective scores for juiciness and softness and to changes in weight and dimensions of steaks from two beef muscles during cooking. J. of Food Sci. 29, 413.

Robertson, S. J. 1962. Rate of rancidity development in refrigerated beef. Unpublished M. S. thesis, University of Georgia, Athena, Georgia.

Satorius, M. J. and A. M. Child. 1938. Effect of coagulation on press fluid, shear force, muscle cell diameter, and composition of beef muscle. Food Research 3, 619.

Siemers, L. L. and F. Hanning. 1953. A study of certain factors influencing the juiciness of meat. Food Research 18, 113.

Simone, M., F. Carroll, and M. T. Clegg. 1958. Effect of degree of finish on differences in quality factors of beef. Food Research 23, 32.

Sleeth, R. B., G. G. Kelley, and D. E. Brady. 1958. Shrinkage and organoleptic characteristics of beef aged in controlled environments. Food Technol. 12, 86.

Thille, J., L. J. Williamson, and A. F. Morgan. 1932. The effect of fat on shrinkage and speed in the roasting of beef. J. Home Econ. 24, 720.

Thomsen, S. 1959. Effect of internal temperature on weight losses, cost per serving, and palatability of chilled top round roasts. Unpublished study, Kansas State University, Manhattan, Kansas.

Tims, M. J. and B. M. Watts. 1958. Protection of cooked meats with phosphates. Food Technol. 12, 240.

Tuomy, J. M., R. J. Lechner, and T. Miller. 1963. Effect of cooking temperature and time on the tenderness of beef. Food Technol. 17, 1457.

Vail, G. E. and L. O'Neill. 1937. Certain factors which affect the palatability and cost of roast beef served in institutions. J. Am. Dietet. Assoc. 13, 34.

Visser, R. Y., D. L. Harrison, G. E. Goertz, M. Bunyon, M. N. Skelton, and D. L. Mackintosh. 1960. The effect of degree of doneness on the tenderness and juiciness of beef cooked in the oven and in deep fat. Food Technol. 14, 193.

Watts, B. M. 1954. Oxidative rancidity and discoloration in meat. Advances in Food Research 5, 1.

Weingarden, M. W., B. Lowe, J. Kastelic, E. A. Kline, A. R. Plagge, and P. S. Shearer. 1952. Physical changes of connective tissues of beef during heating. Food Research 17, 172.

Weir, C. E. 1960. Palatability characteristics of meat. In: The Science of Meat and Meat Products. W. H. Freeman and Company, San Francisco.

Wortham, M. P. 1962. Short-term freezer storage effect on U. S. Good inside round of beef. Unpublished M. S. thesis, Kansas State University, Manhattan, Kansas.

APPENDIX

Form 1. SCORE CARD FOR ROAST BEEF

Judge ______________________ Date ______________________

Sample number	Serving temperature	Aroma	Flavor	Juiciness	Tenderness		
					Initial	Number	Chew score

TEMPERATURE

5. Very hot
4. Hot
3. Warm
2. Lukewarm
1. Cold

AROMA & FLAVOR

3. Freshly cooked
2. Neutral
1. Reheated

JUICINESS

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

TENDERNESS

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

INSTRUCTIONS TO TASTE PANEL MEMBERS

1. Please do not make comments, grimaces, or gestures revealing your feelings about samples before or during the time panel members are examining samples.
2. Complete the scorings of one sample before proceeding to the next one.
3. Score the palatability characteristics in the order listed on the score card.
4. Consider the descriptive terminology under the numerical score of each column.
5. Please do not eat or drink anything for 30 minutes prior to taste panel evaluations.
6. Please do not smoke or chew gum for an hour before doing taste panel evaluations.
7. Take your samples without commenting aloud on your impression of the samples.
8. Take a drink of water, hold it in your mouth a few seconds, and swallow it.
9. Score all characteristics for every sample.
10. Be sure to check descriptive terms for characteristics where indicated.
11. Check your score sheet to make sure you have omitted nothing.
12. Try to concentrate on the scoring of the samples and give it your individual attention.
13. When you have finished scoring, sign your score sheet and return it along with your pencil and sample plate.

Table 11. Weight of roasts for U. S. Good and U. S. Standard grade cooked to 66°, 70°, and 74°C.

U. S. Grade		Internal temperature					
		66°C.		70°C.		74°C.	
		lbs.	oz.	lbs.	oz.	lbs.	oz.
Good		12	13	14	0	16	13
		14	3	14	5	9	13
		13	2	12	6	12	13
		13	2	13	14	13	13
		12	13	15	3	13	11
	Avg.	13	3	14	0	13	6
Standard		15	0	12	5	15	13
		12	8	12	13	15	6
		14	2	15	10	12	6
		14	2	13	8	12	8
		14	5	13	5	15	13
	Avg.	14	0	13	8	14	6

Table 12. Mean values for factors related to cooking time and cooking losses of U. S. Good top round roasts.

Internal temperature		Cooking time	Cooking losses					
			Total		Volatile		Dripping	
		Min./lb.	g.	%	g.	%	g.	%
66°C. (151°F.)		22.03	1439	24.69	792	13.59	645	11.06
		19.57	1093	17.01	780	12.14	309	4.81
		22.44	1590	26.85	1033	17.44	553	9.33
		20.22	1215	20.44	762	12.82	450	7.57
		22.65	1587	27.31	864	14.87	719	12.37
	Avg.	21.38	1385	23.26	846	14.17	535	9.03
70°C. (158°F.)		22.14	1750	27.40	916	14.34	831	13.01
		20.62	1372	21.13	785	12.09	584	8.89
		23.54	1338	23.87	891	15.89	445	7.93
		20.79	1485	23.60	874	13.89	608	9.66
		21.71	1879	27.26	962	13.95	909	13.18
	Avg.	21.76	1565	24.65	886	14.03	675	10.53
74°C. (165°F.)		24.10	2458	32.31	1142	15.01	1109	14.57
		27.65	1255	28.00	829	18.49	423	9.43
		23.75	1757	30.20	1025	17.62	729	12.53
		24.56	1852	29.66	1140	18.26	708	11.34
		22.84	1675	26.92	1102	17.71	570	9.16
	Avg.	24.58	1799	29.42	1048	17.42	709	11.41

Table 13. Mean values for factors related to cooking time and cooking losses of U. S. Standard top round roasts.

Internal temperature		Cooking time	Cooking losses					
			Total		Volatile		Dripping	
		Min./lb.	g.	%	g.	%	g.	%
66°C. (151°F.)		18.00	1515	22.22	895	13.13	614	9.00
		21.92	1434	25.60	715	12.65	717	12.69
		22.19	1264	19.76	177	2.76	984	15.38
		18.43	1577	24.69	839	13.14	734	11.49
		24.12	2060	31.83	1178	18.20	880	13.60
	Avg.	20.93	1570	24.82	761	11.98	786	12.43
70°C. (158°F.)		24.95	1609	28.78	911	16.29	696	12.45
		21.01	1391	23.96	920	15.84	467	8.04
		20.19	1827	25.88	1052	14.90	769	10.89
		22.59	1832	29.94	1045	17.08	784	12.81
		22.55	1602	26.52	859	14.22	741	12.27
	Avg.	22.26	1652	27.02	957	15.67	691	11.29
74°C. (165°F.)		18.22	2489	34.54	1810	25.12	674	9.35
		21.42	1871	26.77	1088	15.56	778	11.13
		22.98	1555	27.75	988	17.63	563	10.04
		24.00	1704	29.96	829	14.57	826	14.52
		23.29	2411	33.73	1390	19.45	1017	14.23
	Avg.	21.98	2006	30.55	1221	18.47	772	11.85

Table 14. Maximum internal temperature rise ($^{o}C.$) of two U. S. grades top round roasts after removal from oven.

U. S. Grade		Internal temperature		
		66°C.	70°C.	74°C.
Good		1.8	2.3	1.5
		3.3	1.8	0.5
		1.4	1.4	1.4
		2.3	-0.9	1.3
		2.8	2.9	0.7
	Avg.	2.3	1.5	1.1
Standard		2.6	2.5	0.2
		3.3	0.3	-0.6
		1.9	0.3	-1.24
		1.9	0.8	0.7
		1.3	1.5	0.1
	Avg.	2.2	1.1	-0.3

Table 15. Time required for two U. S. grades of top round roasts to rise to maximum °C. after removal from oven.

U. S. Grade	Internal temperature		
	66°C.	70°C.	74°C.
Good	65 minutes	70 minutes	75 minutes
	80	80	55
	65	70	65
	70	45	75
	70	75	60
Avg.	70	68	66
Standard	70	60	55
	85	65	55
	80	55	60
	90	50	60
	65	60	60
Avg.	78	58	58

Table 16. Mean values for cooked meat storage losses on two U. S. grades top round roasts.

U. S. Grade		Internal temperature					
		66°C.		70°C.		74°C.	
		g.	%	g.	%	g.	%
Good		99	2.3	86	1.9	84	1.6
		151	2.9	140	2.8	73	2.3
		92	2.2	102	2.4	70	1.8
		122	2.6	126	2.7	199	4.9
		78	1.9	96	2.0	118	2.7
	Avg.	108.4	2.4	110.0	2.4	108.8	2.6
Standard		139	2.7	65	1.7	116	2.5
		84	2.0	85	2.0	124	2.5
		23	.45	85	1.7	103	2.6
		105	2.2	56	1.3	86	2.2
		38	.87	99	2.3	49	1.0
	Avg.	77.8	1.6	78.0	1.8	95.6	2.2

Table 17. Slicing yields and costs of U. S. Good top round roasts cooked to 3 internal temperatures.

Internal temperature	A.P. weight lbs.	oz.	Cost A.P. weight	E.P. weight lbs.	oz.	Sliced portion weight lbs.	oz.	Usable scrap weight lbs.	oz.	No. 3-oz. portion yield	Per cent portion yield	Servings per pound A.P.	Servings per pound E.P.	Cost per pound E.P.	Cost per serving E.P.
66°C.	12	13	$10.88	8	8	7	6	1	2	41	57.6	3.1	4.7	$1.28	$0.27
	14	3	12.07	10	14	9	13	1	1	49	69.2	2.9	3.8	1.11	0.29
	13	2	11.14	8	8	7	3	1	5	41	54.8	3.2	4.9	1.31	0.27
	13	2	11.14	9	3	7	10	1	9	40	58.6	3.3	4.6	1.20	0.26
	12	13	10.88	8	2	6	14	1	4	39	53.7	3.3	5.2	1.34	0.26
Avg.	13	3	$11.22	9	11	8	5	1	6	42	58.8	3.2	4.6	$1.25	$0.27
70°C.	14	0	$11.90	9	3	8	5	0	14	47	58.5	3.0	4.5	$1.29	$0.29
	14	5	12.16	9	11	8	11	1	0	46	60.7	3.1	4.6	1.25	0.27
	12	6	12.24	8	11	7	8	1	3	41	60.6	3.5	5.8	1.41	0.24
	13	14	11.82	9	0	7	11	1	5	39	55.4	3.6	5.5	1.31	0.24
	15	3	12.92	9	13	8	8	1	5	47	56.0	3.2	5.0	1.32	0.26
Avg.	14	0	$12.21	9	5	8	2	1	3	44	58.2	3.3	5.1	$1.32	$0.26
74°C.	16	13	$14.28	10	2	9	10	0	8	49	57.6	3.4	5.7	$1.41	$0.25
	9	13	8.33	6	8	5	13	0	11	33	59.2	3.0	4.5	1.28	0.28
	12	13	10.88	8	6	7	2	1	4	37	55.6	3.5	5.3	1.29	0.24
	13	13	11.73	8	6	7	0	1	6	37	50.7	3.7	6.1	1.39	0.23
	13	11	11.65	9	5	8	0	1	5	46	58.4	3.0	4.4	1.25	0.29
Avg.	13	6	$11.37	8	8	7	8	1	0	40	56.3	3.3	5.2	$1.32	$0.26

Table 18. Slicing yields and costs of U. S. Standard top round roasts cooked to 3 internal temperatures.

Internal temperature	A.P. weight lbs.	A.P. weight oz.	Cost A.P. weight	E.P. weight lbs.	E.P. weight oz.	Sliced portion weight lbs.	Sliced portion weight oz.	Usable scrap weight lbs.	Usable scrap weight oz.	No. 3-oz. portion yield	Per cent portion yield	Servings per pound A.P.	Servings per pound E.P.	Cost per pound E.P.	Cost per serving E.P.
	15	0	$11.85	10	13	9	13	1	0	54	65.4	2.8	3.8	$1.10	$0.29
	12	8	9.88	8	0	7	2	0	14	40	65.0	3.1	4.9	1.23	0.25
66°C.	14	2	11.14	10	10	8	11	1	15	43	61.1	3.3	4.3	1.05	0.24
	14	2	11.14	9	13	8	11	1	2	46	61.5	3.1	4.4	1.14	0.26
	14	5	11.30	9	3	7	6	1	13	40	51.5	3.6	6.9	1.53	0.22
Avg.	14	0	$11.06	9	11	8	5	1	6	45	59.1	3.2	4.9	$1.21	$0.25
	12	5	$ 9.72	7	13	7	0	0	13	39	56.9	3.2	5.0	$1.24	$0.25
	12	13	10.11	8	13	7	11	1	2	44	60.0	2.9	4.2	1.14	0.27
70°C.	15	10	12.32	10	6	9	0	1	6	48	57.6	3.3	4.9	1.18	0.24
	13	8	10.67	8	14	7	11	1	3	43	57.9	3.1	4.7	1.18	0.25
	13	5	10.51	8	11	7	6	1	5	42	55.4	3.2	4.8	1.21	0.25
Avg.	13	8	$10.67	8	14	7	12	1	2	43	57.6	3.1	4.7	$1.19	$0.25
	15	13	$12.48	9	11	8	10	1	1	47	54.5	3.4	5.5	$1.29	$0.23
	15	6	12.17	10	8	9	8	1	0	47	61.8	3.3	5.3	1.24	0.23
74°C.	12	6	9.80	8	6	7	3	1	3	40	58.1	3.1	4.6	1.16	0.25
	12	8	9.88	7	11	6	5	1	6	35	50.5	3.6	5.8	1.28	0.22
	15	13	12.48	10	0	8	3	1	13	43	51.8	3.7	5.8	1.25	0.22
Avg.	14	6	$11.36	9	4	7	15	1	5	42	55.3	3.4	5.4	$1.24	$0.23

Table 19. Mean values for palatability factors related to serving temperature, aroma, flavor, juiciness, initial tenderness, and chew tenderness of U. S. Good top round roasts.

Internal temperature		Serving temperature	Aroma	Flavor	Juiciness	Initial tenderness	Chew tenderness
66°C. (151°F.)		2.81	2.27	2.09	5.00	5.18	5.27
		1.83	2.00	2.16	5.58	5.83	5.91
		2.27	2.09	2.45	5.27	4.90	4.36
		1.36	2.27	1.90	5.00	5.45	5.54
		1.45	2.00	2.18	5.00	5.18	5.27
	Avg.	1.94	2.13	2.16	5.17	5.31	5.27
70°C. (158°F.)		2.41	1.91	2.08	4.91	5.25	5.83
		1.60	1.70	1.80	5.00	5.60	5.30
		1.91	2.16	1.66	4.83	4.58	4.50
		1.27	2.09	1.54	5.36	5.90	5.54
		1.81	1.75	2.08	4.50	5.58	5.91
	Avg.	1.80	1.92	1.83	4.92	5.38	5.42
74°C. (165°F.)		2.00	2.16	1.66	4.16	4.66	4.83
		2.25	2.25	2.16	4.66	5.41	5.50
		1.33	2.11	1.88	4.22	5.11	5.33
		1.54	2.18	2.00	4.54	6.36	6.72
		1.63	1.81	1.81	5.09	5.00	5.18
	Avg.	1.75	2.10	1.90	4.53	5.31	5.51

Table 20. Mean values for palatability factors related to serving temperature, aroma, flavor, juiciness, initial tenderness, and chew tenderness of U. S. Standard top round roasts.

Internal temperature		Serving temperature	Aroma	Flavor	Juiciness	Initial tenderness	Chew tenderness
66°C. (151°F.)		2.41	2.00	2.25	5.33	5.00	5.16
		2.18	1.90	2.09	4.54	5.09	4.45
		1.70	2.00	1.60	4.60	4.80	4.90
		1.72	2.00	2.09	5.00	5.54	6.00
		1.66	1.77	1.88	4.66	4.22	4.66
	Avg.	1.93	1.93	1.98	4.83	4.93	5.03
70°C. (158°F.)		2.25	2.00	1.90	4.54	4.81	4.90
		1.54	2.27	2.18	4.45	4.90	4.45
		1.66	1.88	2.22	5.11	4.44	4.55
		1.09	2.77	1.81	4.45	4.45	4.18
		1.75	2.25	2.25	4.58	5.83	5.83
	Avg.	1.66	2.23	2.07	4.62	4.89	4.78
74°C. (165°F.)		2.20	2.00	2.10	5.00	5.10	5.60
		2.18	2.27	2.18	4.54	4.81	4.90
		1.18	1.90	2.09	4.54	4.54	4.90
		1.75	2.16	2.08	4.66	4.91	5.25
	Avg.	1.81	2.10	2.07	4.64	4.71	5.09

EFFECT OF GRADE AND INTERNAL TEMPERATURE ON PALATABILITY OF REHEATED ROASTED BEEF

by

JOAN RATCHFORD LYON

B. S., Marshall University, 1954

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Since meat accounts for approximately 30% of the institutional food budget, managers are interested in meat preparation methods yielding palatable servings at lowest possible cost. Roast beef is a popular and expensive menu item and presents problems of preparation and service to both small and large food services.

Fifteen U. S. Good and fifteen U. S. Standard inside round beef roasts were procured from a local wholesale distributor. The effect of 2 grades (U. S. Good and U. S. Standard) and 3 end point temperatures of cooking (66, 70, and 74°C) on cooking losses, cost per serving, and palatability of inside round beef that is to be roasted, refrigerated, sliced, portioned, heated, and served was investigated. Data were analyzed by an analysis of variance for a balanced incomplete block design.

Five roasts of each grade were cooked in a rotary hearth electric oven preheated to 300°F to 3 internal temperatures, 66, 70, and 74°C. Internal temperature rise of the roast was registered hourly for 2 hours, then at 30 min. intervals to 60°C, and finally every 5 min. to assigned end point temperature. Volatile, dripping, and total cooking losses; post cooking storage losses; slicing yield; and cost per 3 oz. serving were determined. Twenty-five servings of each roast were heated for 30 min. in a gas reel oven preheated to 350°F and placed in an electric hot cart. Palatability scores were obtained.

Significant differences attributable to grade or internal temperature were not found for total cooking time, cooking time in minutes per pound, dripping loss, volatile loss, and palatability scores. Internal temperature affected average total cooking losses significantly.

A slight rise in post cooking temperature was noted for all but 3 roasts. At each internal temperature, U. S. Good roasts had a slightly lower average total cooking loss than U. S. Standard roasts. In general, average post cooking storage losses were higher for U. S. Good roasts at each internal end point temperature than for U. S. Standard roasts. Average percent portion yield decreased as internal temperature increased for both grades of beef. U. S. Good roasts had higher average cost per pound and cost per 3 oz. serving than U. S. Standard roasts.

Palatability factors considered for the reheated servings of roasted beef were appearance, temperature of serving, aroma, flavor, initial impression of tenderness, tenderness based on chew count, and juiciness. Heated slices of beef of both U. S. Good and U. S. Standard grade remained moist in appearance for approximately 30 min. before rapid deterioration was observable. Average scores for serving temperature of heated portions from cooked roasts were the equivalent of lukewarm.

Judges rated flavor and aroma as neutral. A negative nonsignificant correlation coefficient was obtained for the relationship of aroma and flavor. Initial impression of tenderness and tenderness based on chew count gave a significantly positive correlation. Initial impression of tenderness scores and total cooking losses showed a significant negative correlation. As cooking losses increased, initial impression of tenderness scores decreased or greater toughening of the meat. Tenderness based on chew count and total cooking losses was also negatively correlated although not significantly so.