1951

Good and choice beef rounds: effect of extent of cooking on palatability and edible portion

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GOOD AND CHOICE BEEF ROUNDS:

EFFECT OF EXTENT OF COOKING

ON PALATABILITY AND EDIBLE PORTION

by

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A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Foods

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

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Signature was redacted for privacy.

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1951

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INTRODUCTION

Those concerned with serving foods of high quality at moderate cost recognize a two-fold problem in achieving this goal. First, the best quality of food, consistent with budget allowances, must be purchased. Second, careful attention must be given to the details of preparation so that the finished product is both palatable and economical.

Since the expenditures for meats constitute a large percentage of the total food budget, special attention to the selection and preparation of this menu item is important. The less tender cuts of beef offer many possibilities for variety in the menu at moderate cost. To be most acceptable, these cuts must be cooked in moist heat at relatively low temperatures for a sufficient period of time to soften the large amounts of collagen which they contain.

This study was made in an effort to secure information concerning the comparative palatability and portion cost of cuts from U. S. Good and U. S. Choice beef rounds cooked by moist heat.

Moist heat cooking methods, widely used for preparation of the less tender cuts of beef, include pot roasting, braising, stewing and simmering. In all of these methods the meat is surrounded by water or steam in a covered container, and it is recommended that the cooking process be carried on at low temperature.

Softening of connective tissues and structural proteins is brought about during a relatively long cooking period by the action of the moisture on the tissues. Continuing the cooking process to the point at which connective tissues are completely dissolved results in a product which falls apart when it is lifted from the pan or when attempts are made to slice it for serving. Although such a product may be very tender, it is highly undesirable because it is likely to be stringy in texture, unattractive in appearance, and very difficult to cut into standard portions. If the cooking proceeds to the point at which the plasma proteins become rubbery and tough, the desirable tenderizing effect, which results from softening of the connective tissue, is minimized. In preparing the less tender cuts of beef it is obvious, therefore, that continued cooking after the collagen and structural proteins have been softened has deleterious effects.

Tender cuts of beef, which contain relatively small amounts of connective tissue, present a different problem in cooking. Since these cuts, in their uncooked state, are already tender, the main objectives in cooking them are to develop flavor and to increase the attractiveness of their appearance. The dry heat method has been shown to be the most effective means of achieving desirable cooked products from these tender cuts. The tender cuts generally cooked by dry heat include steaks, roasts, chops, and also ground meats from the less tender muscles. The large cuts, designated as roasts, are most satisfactorily cooked in a medium of dry air at low temperature. Smaller cuts, such as steaks, chops, and ground patties, may be cooked by broiling, pan broiling, or frying. Cooking temperatures for these smaller cuts may be considerably higher than the temperatures used for roasting since the cooking time is comparatively short.

The effect of the extent of cooking on cuts from U. S. Choice and U. S. Good beef rounds cooked by moist heat in this study was observed in relation to changes in cooking weight losses, palatability changes, volume losses, and variation in the cost of the edible portion. Objective tests, as well as palatability scores, were used to evaluate tenderness and juiciness of the cooked meat.

It is hoped that the results of this study may be of interest to those who are concerned with the preparation of palatable meats at economical cost.

REVIEW OF LITERATURE

Palatability and Cooking Losses of Cooked Meats

Extensive investigations, as indicated in the following review of the literature, have shown that factors which affect the palatability, nutritive value, and satiety value of cooked meats are numerous and varied. Cooking methods are of major importance in their effect on such palatability characteristics as aroma, flavor, texture, appearance, tenderness, and juiciness of the finished product. The effect of cooking on the heat labile vitamins and on the amino acids of the structural and muscle proteins are also a vital consideration. Excessive cooking losses incurred by high temperatures or overcooking may affect not only palatability but also the nutritive value and satiety value of cooked meats (8, 11, 20, 21, 22, 23).

In addition to the influence of cooking procedures on the acceptability of meats, many other factors may affect the finished product. These influencing factors include the effect of carcass grade, sex and age of the animal, diet of the animal, and muscle variations within the animal. The length and temperatures of the ripening and aging period (30, 37, 48, 52, 60) have considerable effect on the tenderness and flavor of cooked meats. Temperatures used for freezing and for holding frozen meats have been shown to be related to tenderness and cooking losses (35, 38, 39). Various histological changes in the muscle and connective tissues during rigor, ripening, freezing, and cooking of meats seem to affect the tenderness. Other factors which have been found to influence palatability of the cooked product include the amount and quality of the fat in meats, addition of seasonings, addition of chemical substances for tenderizing, length and conditions of storage periods, breed of animals, and methods of butchering and cutting of the carcass.

Aroma and flavor

Crocker (25) stated that the small amount of blood-like flavor in raw meat resides chiefly in the juice, not in the fiber. Meats cooked to the rare stage appear to undergo the least change in flavor during cooking. The slightly salty taste, characteristic of raw beef, is probably due to the presence of lactic acid, phosphoric acid, sodium chloride, potassium chloride, and other salts.

Development of the "meaty" flavor during the continued cooking of meats, Crocker (25, 26) pointed out, is brought about by certain chemical changes in the fiber rather than in the juices. According to him, this so-called "meaty" flavor is largely odor which is released by chewing the fibers. These odors and accompanying flavors of cooked meats he described as fragrant, moderately acid, slightly burnt, distinctly caprylic, and definitely sulfury. These flavors appear to increase up to 3 or 3.5 hours of cooking and then to diminish gradually. Chemical distillates of the muscle and fat components of cooked beef, Crocker found, contain ammonia, a fishy-smelling amine (possibly methylamine), an indole-like "metallic" odor, a crackery-smelling derivative suggestive of piperidine, and hydrogen sulfide. The variety of chemical substances responsible for these odors and flavors is presumably produced by fragmentation of the constituent amino acids by deamination or decarboxylation and the simultaneous breakdown of the sulfur-bearing amino acids to yield hydrogen sulfide and propionic acid.

Howe and Barbella (42) reported that meat flavors, in the truest sense, consist of stimuli given to the taste buds by inherent organic and inorganic substances such as water-soluble extractives, lipids, small amounts of carbohydrates and salts, or compounds produced from these products and the proteins by cooking. Earlier investigations by Emmet and Grindley (29) indicated that the development of meat flavors is due largely to cleavage of extractives in the meat juices and to cleavage of fat by heating.

Bendall (6) attributed the flavor changes in meat during cooking to partial breakdown of the proteins to amino acids and peptides, to destruction of creatine (no taste) to creatinine (bitter), and to increase in pH due to the coagulation of the proteins by heat with subsequent development of alkaline odors.

Bouthilet (9) reported a close relationship between pH and flavor changes during the cooking of poultry. In his study he ground the uncooked flesh of a young cockerel, mixed it with phosphate buffer solution, boiled the mixture, and graded each sample of flavor evolved. At pH 1.0 to 4.0 a strong chicken flavor was rapidly and completely distilled. At pH 6.2 the chicken flavor had become mild and a "meaty" flavor was noted. From pH 6.2 to 7.0 the chicken flavor disappeared. At pH 7.4 the odor of the mixture was described as basic and there was evidence of some piperidine. When pH reached 8.0, sulfury odors were pronounced and the flavor was likened to that of boiled eggs. At pH 9.0 he reported ammonia and other volatile amines to be the predominant odors.

From this study Bouthilet (9) reported the isolated flavor constituent of poultry to be a weak acid, produced in the flesh during cooking. He found that the compound was easily dialyzable through cellophane membranes and that it could be concentrated on the anion column of an ion exchange operation. The flavor constituent, he reported, could be further purified by steam distillation.

High palatability ratings for aroma and flavor have been found to be closely related to the degree of finish of the animals and the visible fatness of the cuts. From their studies of the relationship of flavor and juiciness to fatness, Barbella and co-workers (4) found that the fat content of 728 rib roasts of beef varied from 7.5 to 57.5 per cent. Increased fatness appeared to be associated with increased desirability of flavor. Considering the effect of various factors on flavor, they found 49 per cent of the total sum of variance in flavor attributable to fatness, 26 per cent attributable to age of animals, 24 per cent attributable to breeding, and 9 per cent attributable to sex. They concluded that desirability and intensity of flavor of fat was largely related to age and that intensity of flavor of the lean was also related to age of the animals. Brannaman and co-workers (12) also reported intensity and desirability of flavor of the lean meat of roasts showed progressive improvement with increased finish.

The effects of ripening, aging, and storage on flavor, aroma, and tenderness of meats have been widely studied and have been shown to have marked influence on palatability. From observing histological, physical, and organoleptic changes in beef during aging, Harrison (37) found the greatest improvement in palatability occurred during the first 10 days of storage at 34 to 36° F. Between 20 and 30 days of storage the beef developed a musty odor and a "high" flavor. Paul (52), in a similar study on beef, found the greatest increase in palatability occurred during the first 9 days of the storage period. After that length of time, "gamey" odors and flavors were observed and development of rancidity in the fat was noted.

Occurrence of rancidity in the fatty parts of meats has been shown to be a very important factor in limiting the length of the storage period for meats (13, 64, 65). Flavor and aroma in meats containing large amounts of fat deteriorate much more rapidly than in leaner meats. Protection from contact with oxygen by sealed moisture and vapor-proof packaging has been shown to delay the onset of rancidity (63). Freezing and low temperature storage have also been found helpful in prolonging the storage period for meats by delaying the development of undesirable aromas and flavors. Low storage temperatures and freezing also retard deterioration of flavors attributable to the action of lypolytic and proteolytic enzymes and microorganisms.

The effect of feed on flavor of poultry was demonstrated by Maw (45) in an experiment in which barley, corn, oats, and wheat were used as the chief constituents of the diet. Other feeding experiments using various fats and oils of pronounced flavor and odor have shown that flavor in fats of the food animals may be affected by these dietary constituents. Diets which contain large amounts of unsaturated fatty acids are known to result in soft fat in meat animals which has a greater tendency to become rancid than fatty tissue developed by animals on a balanced diet with normal fat sources (13, 40, 41, 64, 65).

Flavors vary among muscles of the same animal owing to differences in chemical composition of the muscles. Paul and McLean (54), studying variations in muscles of veal, found wide variation in cooking losses and palatability characteristics among different muscles of the same animal.

The extent of cooking has been shown to be very closely related to the flavor and aroma of meats. The slightly acid taste of uncooked and rare meats undergoes a series of changes as the degree of cooking progresses. Cleavage of the extractives and fats of meats by heating results ultimately in the development of alkaline odors and of flavors which are both bitter and sulfury (5, 6, 9, 25).

The addition of various chemical salts and solutions to meats has been studied from the standpoint of effect on flavor and texture. From the results of an investigation of the factors influencing slicing quality and palatability of canned beef, Green (31) observed marked improvement in the flavor of beef injected with a solution of sodium chloride or a combination of sodium chloride and lactic acid. Injections of lactic acid alone had no apparent effect on any of the palatability characteristics.

Tenderness

In his discussion of quality in meats and meat products, Hankins (33) stated that, except for unwholesomeness, there is no attribute of meat more of a liability than toughness. Basically, the tenderness of cooked meat is dependent on the amount and kind of connective tissue in the muscle and on the way in which the meat is cooked. Muscles containing relatively small amounts of connective tissue are not tenderized by cooking, according to many investigators. A study by Ramsbottom and coworkers (55) indicated that decreased tenderness of certain muscles after cooking may be associated with coagulation and denaturation of the muscle protein together with varying degrees of shrinkage and hardening of the muscle fibers. On the other hand, muscles with a high collagen content may be made more tender by slow cooking in moist heat because of the swelling and softening of the collagen.

Factors other than muscle composition and cooking method may also affect the tenderness of cooked meat. Among such influencing factors are the age of the animal, carcass grade, the length and conditions of the aging and ripening period, freezing, extent of cooking, temperature of cooking, and chemical substances added during cooking.

For tenderizing effect, according to Dean (27), interior temperature must be within the range which disintegrates the connective tissue of the tough cuts. In a study of the effect of cooking temperatures of 110° C and 175° C on paired tough cuts of beef, Dean concluded that the oven temperature did not affect tenderness, provided that all meat reached the same internal temperature. Tenderness, determined both by shearing force and judges' scores, was found in this study to increase as internal temperature increased. Tests by Child and Sartorius (17) also indicated no difference in the tenderness of semitendinosus muscle of beef cooked to 58° C internal temperature in ovens at 125°, 150°, 175°, and 200° C.

Using the penetrometer to test tenderness in a study of the effect of the extent of cooking on rib roasts of beef, Noble and co-workers (50) reported greater penetration in roasts cooked to 75° C than in those cooked to 61° C internal temperature. Penetration was found to be greater for loins than for rounds of the same animal.

In a study of the changes occurring in three grades of beef during aging, Harrison (37) found that, in general, increases in time of heating and temperature were accompanied by an increased degree of softening of the connective tissue. Winegarden (67) also found in her investigation of the physical and histological changes of connective tissues of beef during heating in water that the degree of softening of collagen increased as temperature and time of heating increased. From this it was inferred that cuts of beef containing large amounts of collagen could be tenderized by long cooking with moist heat.

Some changes in histological structure were noted by Winegarden (67) in collagen heated at 95° C for 64 minutes. Structural changes in collagen after heating were also found by Harrison (37). Further studies by Harrison led her to the conclusion that the histological structure of muscles was probably related to the tenderness of beef.

Individual muscles within a carcass vary markedly in tenderness. A study by Ramsbottom and co-workers (55) on the comparative tenderness of fifty of the large muscles of beef substantiated this idea. From the results of their work, Ramsbottom and co-workers (56) suggested that extending the practice of grouping muscles of similar tenderness for cutting roasts would be a great aid in preparing meats with maximum palatability.

Although fatness of carcass is related to carcass grade and carcass grade appears to be related to tenderness, the work of Hankins and Ellis (34) indicates that variations in tenderness are caused mainly by factors other than fatness as such. Their conclusions were based on an extensive study of the amount of fat and the shear force values for cuts from 728 cattle and 924 lambs.

Aging and ripening appear to have a marked effect on tenderness.

Paul (52) noted a decrease in force required to shear beef samples as the storage period increased from 0 to 18 days. She reported the most tender muscles of the hind quarter to be psoas major, gastrocnemius, and adductor, in that order. No significant difference was found in tenderness among the semitendinosus, semimembranosus, vasti, and biceps femoris muscles. Studies by Steiner (60) indicated that change in tenderness during ripening varies greatly with age and sex of the animal and from one animal to another.

In studying the tenderizing effect of aging on porterhouse steaks, Hiner and Hankins (38) reported that steaks aged 35 days were more tender than comparable steaks aged only 5 days. In this investigation they found that beef aged 5 days at 34° F and then frozen at -10° F was as tender as beef ripened 35 days at 34° F.

Hiner and Hankins (39), using paired short loins, observed that cuts refrigerated at 34° F were the least tender of all the roasts checked in their study of the effect of storage temperatures. They found that roasts frozen at -10° F and -40° F were more tender than those frozen at 20° F; however, no significant difference in tenderness was noted between the roasts frozen at -10° F and -40° F. A similar conclusion regarding the increased tenderizing effect of sub-freezing temperatures on beef was reported by McClurg (47). He found that roasts frozen at -10° F appeared to be more tender than those frozen at 0° F.

The effect of cooking temperatures on tenderness has been widely investigated. In general, low cooking temperatures are considered to have a greater tenderizing effect on the less tender cuts than high cooking temperatures. Cover (19) reported well-done round-bone chuck and rump roasts to be much more tender when cooked at 125° C than when cooked at 225° C. Well-done standing rib roasts and half-hams were also found to be more tender when cooked at the lower temperature than when cooked at the higher temperature. Little difference was noted in the tenderness of medium-rare rib and chuck roasts cooked at these two temperatures. Cover suggested that the tenderizing effects noted might be attributable to the longer cooking time at the lower temperature rather than to the temperature alone.

Tenderness, as well as improvement of flavor, of canned beef was found by Green (31) to be increased by the injection of sodium chloride solution and by the injection of a combination of sodium chloride and lactic acid. Microscopic observations led Green to the conclusion that tenderness of canned beef was related to microscopic changes in muscle and connective tissue during the processing of canned meat.

Shrinkage and denaturation of muscle fibers has also been reported by some investigators to be related to tenderness. Sartorius and Child (57) noted shrinkage in the diameter of muscle fibers of the semitendinosus of beef during cooking to 67° C internal temperature. During the cooking process the muscle fibers coagulated and became less tender. As cooking progressed, the fibers squeezed out fluids and a loss in weight and volume resulted. The extent of denaturation appeared to depend on the internal temperature reached during the cooking process.

<u>Texture and appearance</u>

Texture and appearance of cooked meats are important to those seeking to please the consumer because of the profound influence of eye-appeal in food selection. Although texture and appearance may or may not be directly related to flavor, poor ratings for these characteristics may cause a consumer to reject a sample entirely on the basis of its poor appearance. The effect of various factors on the appearance and texture of cooked meats are seldom treated except in conjunction with the other palatability characteristics. Brady (10) reported that texture is dependent on the size of the fiber bundles in muscle, the larger bundles being associated with finer texture. He further suggested that fine muscle texture is probably indicative of tenderness.

Juiciness and press fluid

Juiciness of cooked meat is associated with high palatability, and both the quality and quantity of juice appear to influence acceptability. Among factors which have been found to affect the juiciness of cooked meat are the amount of carcass finish, extent of cooking, method of cooking, length and conditions of ripening and storage, cooking temperatures, and breed of animals.

Rapid increase was noted by Barbella and co-workers (4) in the quantity of juice in roasted beef with increased fatness, determined by ether extraction, up to a fat content of 22.5 per cent. Breeding, according to this group, was the most important among the factors considered in relation to the quantity of juice in cooked beef. Other factors considered were fatness, age, and sex. Fat beef roasts were reported by Thille and co-workers (62) to be less dry than lean roasts.

From a study of the effect of storage on palatability characteristics and physical changes in beef, Paul (52) noted a drop in the amount of press fluid in the muscles during the first few days of storage at 34° to 36° F. This decrease was followed by a sharp increase in press fluid between the 9th and 18th day of storage. A report by Paul and Child (53) on the effect of freezing indicated that unfrozen beef was significantly higher in press fluid than beef frozen and then thawed at 175° C.

In studying the influence of four cooking media on the amount of press fluid in beef roasts, Harrison (36), using samples taken near the surface of the roasts, reported that roasts cooked in air were highest in press fluid and those cooked in steam were lowest. However, no significant difference was noted in the amount of press fluid in samples taken from the center of roasts cooked in air, fat, water, or steam. Judges' scores for juiciness indicated no detectable difference in the effect of cooking media used.

From studies on the effect of exterior temperatures on press fluid, Child and Sartorius (17) reported roasting temperatures of 125°, 150°, 175°, and 200° C had no noticeable effect on amounts of press fluid in the semitendinosus muscle of beef heated to 58° C internal temperature or in pork loins cooked to 84° C internal temperature. Likewise, standing ribs, cooked to 58° C, showed approximately the same amount of press fluid whether cooked at 150° C constant temperature, 200° C constant temperature, or at 150° C preceded by searing at 260° C.

Extensive investigations by many workers have shown a close relationship between internal temperature and amount of press fluid. Sartorius and Child (58), although they found no correlation between juiciness scores and amount of press fluid, reported a decrease in press fluid in semitendinosus of beef by increasing internal temperature from 67° C to 75° C. However, they found no such decrease by increasing internal temperature from 58° C to 67° C. Rib roasts of beef cooked to 61° C internal temperature were reported by Noble and co-workers (50) to be juicier than comparable roasts cooked to 75° C. Beef rounds, according to their study, were juicier at both temperatures than the corresponding rib roasts. Increasing internal temperatures from 71° to 88° C for veal roasts, according to Paul and McLean (54), resulted in lower juiciness scores. These workers also reported a highly significant difference among individual muscles in juiciness scores for the three sizes of veal animals used in the study. Child and Moyer (16) reported that samples taken from the center of beef roasts contained more press fluid than samples taken near the surface of the same roasts. This they attributed to differences in internal temperature of these areas of the roasts. Similar tests on pork roasts, however, did not show appreciable differences of press fluid in samples from different parts of the roasts.

Cooking weight losses and shrinkage

Excessive cooking weight losses in meats have been found by many workers to be related to a decrease of palatability. The juiciness of cooked meats appears to be particularly affected by high cooking losses.

Factors which have been studied in relation to the total weight losses of meat during cooking include the amount of finish of the carcass, cooking temperatures and time, internal temperature, carcass grade, degree of ripening, individual muscle variation, size of cuts, freezing, and methods of thawing.

In early studies Grindley and Mojoinner (32) reported an increase in cooking losses with increased length of the cooking period and with higher cooking temperatures used in preparation by boiling, sautéing, pan-broiling, and roasting. According to their report, smaller relative losses were noted in larger pieces of meat than in smaller pieces cooked by boiling and roasting. They reported great differences in the amount and kind of losses from different cuts of the same kind of meat.

Morgan and Nelson (49), from studies of the effect of metal skewers on shrinkage and speed of heat penetration in beef roasts, reported a marked decrease in cooking time and cooking losses in roasts in which skewers were used. They observed no appreciable increase in losses of roasts cooked at 250° C over roasts cooked at 175° C and suggested that this was probably explained by the reduction in total cooking time at the higher temperature.

Studies by Alexander and Clark (1) of shrinkage during the roasting of lamb and mutton of Choice, Good, Medium, Common, and Cull grades showed greater cooking losses, principally fat, from the higher grades. Water losses did not follow grade consistently. Cooking losses and cooking time decreased as the ripening period increased. They observed that the average oven temperatures had more effect on shrinkage than initial searing temperatures used in conjuction with lower finishing temperatures. On the whole, lower oven temperatures resulted in smaller shrinkage of roasts cooked to the medium-to-well-done stage. In roasts cooked to 83° C internal temperature, no difference was noted between losses of roasts cooked at 125° C and those cooked at 175° C. They concluded from these studies that the degree of doneness influenced cooking losses more than the oven temperatures and suggested that excessive losses might be attributable to overcooking.

Another study by Alexander and Clark (2) on the effect of grade, style of cutting, and method of roasting on losses of standing and rolled ribs of beef showed smaller evaporation losses and greater dripping losses from higher grade animals. Standing ribs shrank less and cooked quicker than boned and rolled ribs. However, expressed in terms of the weight of the roasts before boning, the cooking loss of the rolled roasts was slightly less than that of the unboned cuts. A cooking temperature of 125° C resulted in shrinkage of 9.3 per cent in this study, whereas a cooking temperature of 175° C resulted in a 16.4 per cent shrinkage when the meat was roasted to the rare stage. Little difference was noted between losses at the two oven temperatures when roasts were cooked to the well-done stage. Searing of roasts did not reduce shrinkage. These workers noted that shrinkage appeared to be more dependent on the cut of meat than on searing temperatures used.

Child and Fogarty (15), in a study of the effect of internal temperature on cooking losses and press fluid of beef muscle, found an inverse relationship between percentage of press fluid and total cooking losses of muscle cooked to 75° C internal temperature. No relationship was noted between press fluid and cooking losses for muscles cooked to 58° C internal temperature.

Additional studies by Child and Sartorius (17) on the effect of exterior temperature upon press fluid, shear force, and cooking losses of roasted beef and pork muscles indicated that cooking losses of beef, at 58° C internal temperature, increased when higher oven temperatures were used. Cooking losses of pork did not appear to be affected by differences in oven temperatures.

Cline and co-workers (18), after studying the effect of cooking methods on quality and palatability of beef, reported that low oven temperatures resulted in lower cooking losses and greater palatability than did high oven temperatures. They found no relation between size of cut and total percentage of loss. According to their studies, the addition of water to beef during the roasting period caused a decrease in palatability and an increase in total cooking losses. Judges' scores for this study indicated that increased shrinkage was accompanied by a decrease in flavor, juiciness, and tenderness.

Application of heat over 60° C to beef, fish, and flesh foods, according to McCance and Shipp (46), resulted in shrinkage of the proteins and in the expression of juices. Increasing the temperature from 80° C to 100° C and from 100° C to 120° C accelerated the rate of shrinkage.

McCane and Shipp also found that half inch slices of beef, weighing about 50 grams, cooked in boiling water for 6 hours lost weight and water very rapidly during the first 30 minutes of cooking and then lost no more. Losses of salt, non-protein nitrogen, and purine nitrogen occurred throughout the cooking period but were most rapid during the first 30 minutes of boiling.

Further studies by these workers, using 1500 gram pieces of beef, showed losses of weight comparable to those noted for the 50 gram pieces during a 6 hour boiling period. However, the rate of loss during the early part of the cooking period was slower for the larger pieces than for the smaller ones. The entire 6 hour boiling period was necessary to bring the large pieces to the same percentage of loss shown by the 50 gram pieces at the end of the first 30 minutes of cooking.

Another report by McCance and Shipp showed that the greatest loss of weight for pot-roasts had occurred by the time the internal temperature had reached 90° C. They found that cooking beef chuck roasts beyond the time at which an internal temperature of 90° C was reached resulted in no marked increase in the total weight losses. Roasts held 120 minutes after they had reached an internal temperature of 90° C never showed an increase of more than 5 per cent over the losses of roasts cooked just to 90° C.

Total cooking losses of muscles of beef round, according to Paul (52), did not vary significantly among the muscles studied or with increased length of storage at 34° to 36° F for a period of 18 days.

Thille and co-workers (62), studying the effect of fat on shrinkage and speed of roasting, reported greater total cooking losses for fat roasts than for lean. Volatile losses, however, were reported to be less for the fat roasts than for the lean.

Methods of Evaluating Palatability of Meats

Subjective methods

Despite the difficulties encountered in evaluating acceptability of foods by subjective methods, most workers recognize this as an important method of determining palatability. Bengtsson and Helm (7) have reviewed important points to be observed in planning organoleptic testing. Crist and Seaton (24) have pointed out in their article on the reliability of organoleptic tests many of the subtle problems to be considered in developing reliable subjective measurements of food acceptability. Overman and Li (51) have discussed the problems associated with the dependability of judges' scores used as a means of evaluating the acceptability of foods.

Objective methods

Child and Baldelli (14), in their article reporting the development of apparatus and methods for determining the amount of expressible press fluid in beef muscle, described a press used for objective evaluation of juiciness. Tanner and co-workers (61) also described a method for mechanical determination of juiciness of beef and pork muscle by means of a hydraulic press. Their findings showed no close correlation between results obtained by the hydraulic press method and the results of taste panel scores for juiciness of beef cooked to 58° C internal temperature. At higher internal temperatures, however, they reported an inverse relationship between the juiciness scores and the amount of expressible fluid, as determined by the hydraulic press method. From their results, it appears that the type of meat (beef, lamb, or pork) seems to be a complicating factor in the scores for juiciness. Their tests indicated that when the samples of these three types of meat showed the same percentage of press fluid, beef samples were consistently rated highest and pork samples lowest in juiciness according to the judges' scores. From reports of numerous investigations, it appears that it is not always possible to obtain consistent relationships between press fluid values and subjective scores for juiciness.

Various devices have been designed to determine the tenderness of foods. A shearing apparatus, which measures the pounds of force required to cut through a cylinder of muscle of prescribed diameter, has proved very satisfactory as an objective means of determining tenderness of meats. By using careful techniques in the preparation of the sample and in carrying out the test, it is possible to achieve a high degree of correlation between shear test results and tenderness scores.

Mitchell and co-workers (48) offered a refined chemical method for determining the amounts of collagen and elastin in meats. Their method, with further refinements, is widely used by a number of experiment stations as a means of measuring tenderness. Mackintosh and co-workers (44), in studies of tenderness of 12 mature steers and 69 yearling steers, reported that as shear values rose the collagen nitrogen values also rose. These rises in shear force and collagen nitrogen were accompanied by a decline in tenderness as determined by subjective scores. These workers concluded that significant correlations between shear values and the amount of collagen nitrogen and also between tenderness scores and the amount of collagen nitrogen indicated that the three methods were probably measuring the same factor, which was apparently related to tenderness.

Bendall (6) reported the effects of cooking on creatine-creatinine, phosphorus, nitrogen, and pH values of raw, lean beef as a means of determining chemical changes which affect the palatability of the finished product. Although information showing correlation of these chemical changes with results of taste tests is quite limited at present, additional investigations may later prove these chemical methods to be of considerable importance in evaluating palatability of foods objectively.

Combination methods

Since the final test of cooked meat is its acceptability for consumption as food, it appears that the eating-quality is an important means of evaluating palatability. Lowe and Stewart (43), in their report on subjective and objective tests as food research tools, suggested that a combination of subjective and objective testing methods may be expected to give a better indication of the acceptability of cooked meats than either kind of testing used alone. They pointed out that subjective testing, whereas it is difficult to control, may give valuable information concerning the finished product which can be obtained in no other way. In spite of the recognized deficiencies of subjective scoring as a measure of palatability, Dove (28), has stated that all measures of the value of a food, in the end, must be liable to the subjective response of the consumer. He also suggested the use of a "subjective-objective" approach to the problem of acceptability evaluation.

Bate-Smith (5) expressed the opinion that there may be much merit in the use of weighted values for individual characteristics making up the total palatability evaluation of a given food when subjective methods are used.

Recognizing the shortcomings of subjective methods for determining the acceptability of foods, many investigators have combined this method with various objective tests which have been devised for measuring certain palatability characteristics. At the present time, however, the number of objective tests which have proved satisfactory for determining acceptability is still rather limited.

METHOD OF PROCEDURE

Preparation of the Pot Roasts

Two pairs of U. S. Good and two pairs of U. S. Choice grade beef rounds, rump on, were used for this study. Carcass grade designations, throughout this study, refer to the new classifications for beef grading which became effective January 1, 1951. Pertinent information concerning the rounds which were used follows.

Table 1. Data on Beef Rounds Used in Study

Animal No.	Carcass Grade	Weight of Rounds[1] Left	Weight of Rounds[1] Right	Slaughter Date	Cutting Date
I	U. S. Good	59.00	60.50	4/17/51	4/27/51
IV	U. S. Good	76.25	75.00	6/15/51	6/25/51
II	U. S. Choice	67.00	68.50	4/17/51	4/27/51
III	U. S. Choice	73.25	73.00	6/15/51	6/25/51

The rounds were purchased from the Iowa Packing Company of Des Moines and were delivered to the animal husbandry meat laboratory where they were allowed to hang in the cooler at 34 to 36° F until the tenth day after slaughter. Cuts were then prepared by dissecting the semitendinosus, rectus femoris, vastus lateralis, and adductor muscles from the rounds. These muscles were trimmed for cooking as individual pot roasts. The biceps femoris was dissected and cut crosswise into three parts and the semimembranosus was divided into two parts to make all cuts as comparable as possible in size and shape.

[1]Weight in pounds after 10 days ripening at 34 to 36° F.

Storage of Pot Roasts

After the muscles were dissected and trimmed for pot roasts, they were labeled, wrapped in heavy locker cellophane, and frozen at -30° C for a period of 24 to 72 hours. They were then removed to storage lockers and held at -10° C until the time of defrosting prior to cooking. Storage periods for the cuts ranged from 31 days to 53 days.

Preparation of Pot Roasts for Cooking

Cuts were defrosted at refrigerator temperature, 7 to 10° C, for 36 to 48 hours to an approximate internal temperature of 0° C before cooking.

Upon removal from the refrigerator, the pot roasts were unwrapped and weighed. Volume of the uncooked pot roasts was taken by the displacement method in water at 25 to 27° C. Measurements of length, width, and depth were taken for each cut. A thermometer was inserted in each cut so that the bulb was at the center of the cut.

The Cooking Process

Each pot roast, without browning, was placed on a trivet in a preheated Dutch oven with the meat thermometer extending through a hole in the lid. Each Dutch oven was then placed in a separate gas oven, which had been preheated to 150° C. The ovens were equipped with glass panel doors for easy observation of thermometers.

Readings for pot roast and oven temperatures were recorded at 20 minute intervals until the cuts reached 80° C internal temperature. As the internal temperature approached 90° C, readings were taken with increasing frequency. Gas consumption records were kept throughout the preheating and cooking periods.

All pot roasts, upon reaching an internal temperature of 90° C, were weighed, measured, and checked for volume loss by displacement in boiling water. Drippings were also weighed at this time. One pot roast from each pair was then returned to the 150° C oven and held for an additional hour. During this holding period, temperature readings were taken at 20 minute intervals. At the end of the holding period, the pot roasts were again weighed, checked for volume loss, and measured. Drippings were again weighed, and the final internal temperature of the meat was recorded.

Drippings were poured into 500 milliliter graduate cylinders for measuring the fat losses and for observing the appearance of the drippings.

Preparation of Samples

The pot roasts were allowed to cool a minimum of 30 minutes before any samples were prepared for scoring and testing. After cooling, the meat was sliced for scoring and samples were removed for shear and press fluid tests.

Samples for scoring

One slice was made across the grain at the anterior end of the muscle with a sharp knife to get a straight edge for machine slicing. From this end of the pot roast a distance of 2.5 inches was measured and another cut, parallel to the first, was made with the knife. A sample for testing with the shearing apparatus was removed from the center of this 2.5 inch section of the muscle. Then this section was cut from the anterior end, into one-fourth inch slices on a mechanical slicer. From every pot roast each judge received a slice in the same relative position from the anterior end of the muscle for scoring.

Samples for scoring were wrapped in heavy cellophane or slipped into plastic envelopes as soon as they were cut.

Samples for shear force tests

Samples for the testing of tenderness on a shearing apparatus, were removed from the center of the 2.5 inch section taken from the anterior end of the muscle as described above. The apparatus was previously constructed along the principles of the Warner-Bratzler shearing apparatus in the Iowa State College instrument shop. The removal of this sample was effected with a steel cylinder, 1 inch in diameter, sharpened to a cutting edge at one end. The sample was wrapped in heavy cellophane until tests were made on it.

Samples for press fluid

Samples to be tested for press fluid were obtained from a center strip of the one-fourth inch slice adjacent to the last slice removed for scoring. This strip was wrapped in heavy cellophane until tested. At the time of testing, three samples of desired size, weighing between 1.5 and 2.0 grams, were cut from each strip with dissecting scissors and weighed on an analytical balance. They were wrapped immediately in standardized muslin covers with double blotting paper pads, one-half inch square, on the top and bottom of the wrapped sample. This sample was then wrapped in a second muslin cover and tested on the pressometer.

Tests and Records

Subjective tests

One sample of each pot roast was scored by a panel of four judges. Scoring was based on a scale of 0 to 10 for aroma, appearance, flavor, texture, tenderness, and juiciness. Descriptive terms for these characteristics were also listed for checking by judges.

Appearance of drippings for each pot roast was subjectively evaluated by observation of the drippings in 500 milliliter graduate cylinders.

Objective tests

Total losses were recorded for all pot roasts at 90° C and after the holding period for those which were held one hour after reaching an internal temperature of 90° C.

Drippings were weighed for all pot roasts when the internal temperature of the pot roasts reached 90° C. Drippings were weighed again at the end of the one hour holding period for those pot roasts which were held an hour after reaching an internal temperature of 90° C.

Volatile losses were figured by deducting the dripping losses from the total losses for pot roasts at 90° C internal temperature and after the holding period.

Volume losses were obtained for pot roasts by noting changes in displacement of the uncooked cuts as compared with displacement of the pot roasts at an internal temperature of 90° C and after the holding period.

Fat losses in the drippings were measured after the warm drippings were poured into 500 milliliter graduate cylinders and cooled. Readings were taken in milliliters and multiplied by 0.9 to covert the fat loss from volume to weight.

Juiciness was objectively evaluated by determining the amount of press fluid which could be expressed from samples of known weight under pressure of 250 pounds per square inch for 5 minutes in the pressometer. Samples were prepared as previously described. After pressing, samples were unwrapped at once and weighed again on an analytical balance. The percentage of press fluid was calculated by dividing the difference between the initial and the pressed weights by the initial weight of the sample. Three samples from the sample strip of each pot roast were tested by the pressometer method.

Tenderness was objectively measured by testing samples, prepared as previously described, on the shearing apparatus, which measures the force in pounds required to cut through a cylinder of muscle 1 inch in diameter. Five shear readings were made from the sample taken from each pot roast.

Fuel consumption record

Fuel consumption records included both the gas required for preheating the ovens to 150° C and that used for the cooking and holding periods.

Cost data for edible portion

The cost data included the initial cost of the rounds, deductions for trim and waste from the wholesale cut, the percentage cooking weight losses, and the cost of fuel used in the entire cooking period, including the preheating of the ovens.

The purchase price of the first pair of U. S. Good grade rounds was $0.5700 per pound and of the second pair was $0.5595 per pound. Unit price of the first pair of U. S. Choice grade rounds was $0.5950 and of the second pair was $0.5595. Market conditions at the time of the second purchase were such that there was no difference in the unit cost between the Choice and Good grades of this particular wholesale cut. Generally, however, the buyer would expect the unit cost of the Choice grade to be slightly higher than that of Good grade rounds.

Cost of fuel for this study was based on the rate of $1.00 per 500 cubic feet of gas[1]. Fuel cost for regular institution use, however, would not be likely to constitute as large a part of the edible portion cost, since the rate decreases appreciably as the total consumption of gas increases.

[1]Ames Gas Company rate.

RESULTS AND DISCUSSION

Cooking Weight Losses

Total losses

The total cooking weight losses of cuts from U. S. Choice and U. S. Good rounds cooked to 90° C internal temperature were very similar. From an average of all cuts, from both left and right sides, it was found that average total cooking losses for Good cuts were only 0.60 per cent higher than for comparable Choice cuts at 90° C internal temperature. See Table 2, which contains the data for the average total cooking weight losses for cuts from two pairs of Good rounds and two pairs of Choice rounds, graded according to the specifications of the new grading system for beef which became effective in January of 1951. Analysis of variance of total cooking losses showed F values to be non-significant for carcass grades, for animals, and among animals of the same grade.

Much greater variation in percentage of total cooking weight losses was noted among different cuts of the same round than between the two grades of beef. For the nine cuts used from the two pairs of Good rounds, cooked to 90° C internal temperature, average total losses ranged from 29.9 to 40.3 per cent. The range of average total cooking losses among corresponding Choice cuts was from 30.0 to 38.3 per cent. Analysis of variance showed the variation in total cooking losses attributable to individual muscles to be significant at the 1 per cent level of probability.

The variation of total cooking losses among the individual cuts is clearly shown in Figure 1. Among the cuts which consistently incurred a total cooking loss greater than 35 per cent in both Choice and Good grades

Table 2. Average percentage total cooking weight losses of U. S. Good and U. S. Choice cuts. Muscles from left side cooked to 90° C; those from right side cooked to 90° C and then held in 150° C oven 1 hour longer.

Effect of Treatment	Losses incurred by cooking to 90° C		Losses incurred by cooking to 90° C plus 1 hour holding at 150° C	
Carcass Grade	Good	Choice	Good	Choice
Muscles, left side				
Rectus femoris	38.7	36.8		
Semitendinosus	29.9	31.0		
Biceps femoris, upper	32.7	33.0		
Biceps femoris, middle	34.1	33.9		
Biceps femoris, lower	32.7	30.1		
Vastus lateralis	35.2	36.7		
Semimembranosus, upper	36.3	37.7		
Semimembranosus, lower	37.2	36.9		
Adductor	36.8	38.3		
Average of all cuts	34.8	34.9		
Muscles, right side				
Rectus femoris	36.6	37.8	40.8	40.2
Semitendinosus	30.5	30.1	36.6	35.6
Biceps femoris, upper	31.7	30.0	37.0	35.2
Biceps femoris, middle	34.9	33.1	39.2	37.6
Biceps femoris, lower	32.0	31.1	37.7	36.8
Vastus lateralis	36.2	31.2	39.5	37.1
Semimembranosus, upper	37.1	36.0	40.6	38.8
Semimembranosus, lower	40.3	38.3	43.7	41.2
Adductor	37.5	37.9	40.3	40.7
Average of all cuts	35.2	33.9	39.6	38.2

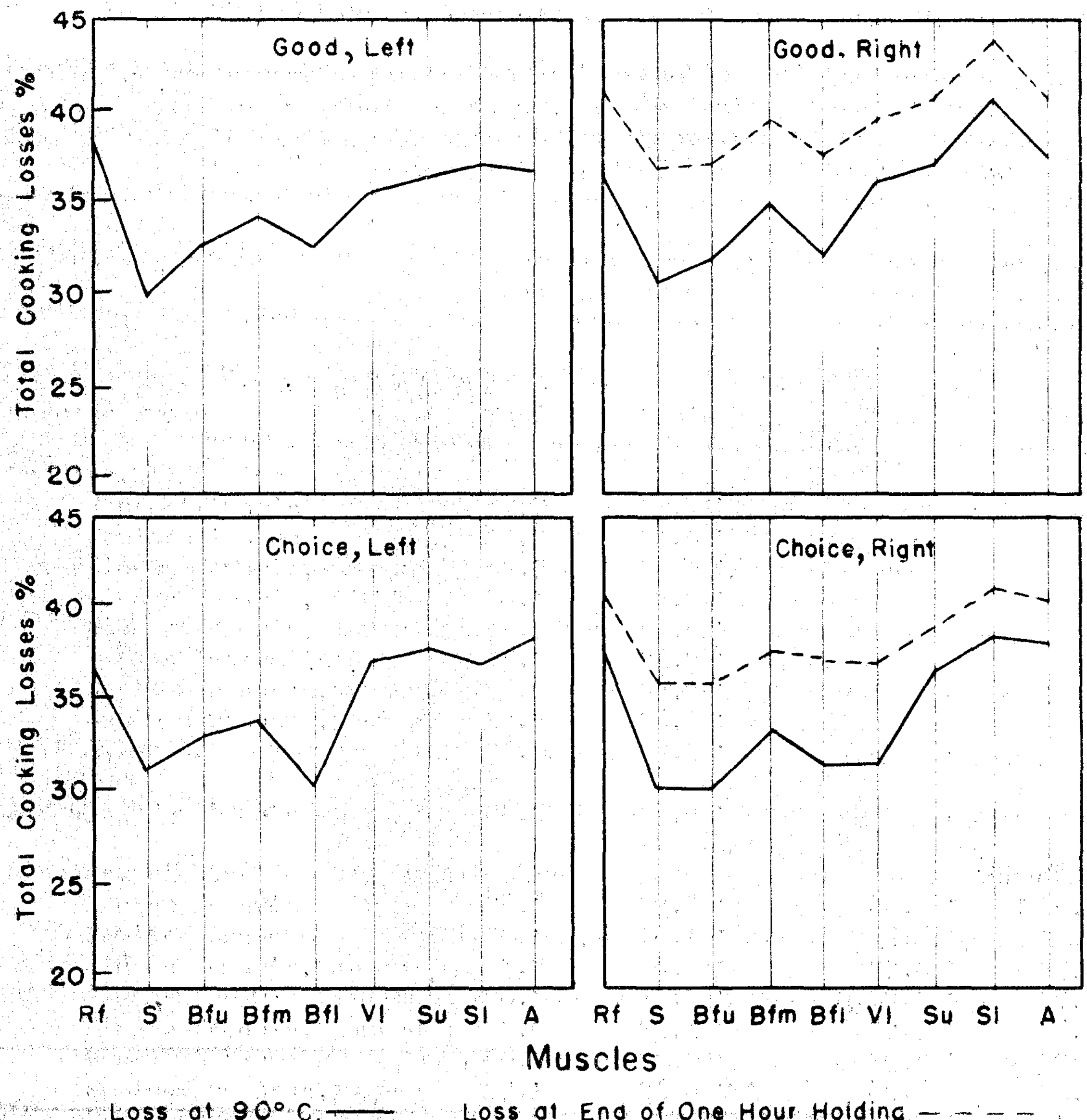


Figure 1. Average Total Cooking Weight Losses. Space between solid and dotted lines represents additional loss during the one hour holding period after the pot roasts reached 90° C internal temperature.

were those taken from the rectus femoris, adductor, and the upper and lower semimembranosus muscles. The lowest total cooking losses occurred consistently in both grades in the semitendinosus, which averaged 30.2 per cent loss in Good grade and 30.6 per cent loss in Choice grade. Average total cooking losses for the vastus lateralis and the three cuts from the biceps femoris fell in a less distinct pattern between 30 and 35 per cent.

No significant difference was notted in the total losses between the Choice and Good cuts held an additional hour at 150° C after the pot roasts had reached 90° C internal temperature. The average total loss for the Good cuts after the holding period was only 1.4 per cent greater than for comparable Choice cuts. The total losses after the holding period ranged from 36.6 to 40.8 per cent for Good and from 35.2 to 40.7 per cent for Choice grade.

During the additional hour of holding after the internal temperature of the pot roasts had reached 90 C, Good cuts incurred an additional average loss of 4.4 per cent and Choice cuts incurred an additional average loss of 4.3 per cent of their initial weight. The rate of loss obviously was slower during this last hour of holding than in earlier stages of cooking. The amount of increases in total loss during this period was large enough, however, to warrant the attention of those concerned with the economical production of well-prepared meat.

During the holding period after the pot roasts had reached an internal temperature of 90° C, the increase of internal temperature showed no consistent pattern among the individual cuts or between the grades of beef. Final internal temperatures after the holding period ranged from 92° C to

98° C. The final internal temperature of two thirds of all the cuts, which were held an hour after they had reached 90° C, was within the range between 95° C and 97° C. In the case of the upper semimembranosus from the round of Choice animal II, the internal temperature dropped from 90° C to 83° C after the objective measurements were taken. During the one hour holding period, the internal temperature of this cut increased only to 87° C.

Cooking time, expressed in terms of minutes per pound of raw weight, showed a fairly consistent pattern among the individual cuts cooked to 90° C internal temperature. The adductor muscles required 34 minutes per pound, and the upper biceps femoris required an average cooking time of 50 minutes per pound to reach 90° C internal temperature. The cooking time for other cuts fell within this range. Since an arbitrary holding period of one hour was set for all cuts, without regard for the size of the cut, the figures for total cooking time per pound do not give a true picture of the differences in the rate of heat penetration among the different cuts which were held the additional hour.

Dripping losses

Dripping losses, as shown in Table 3, did not vary significantly between Good and Choice grades cooked to 90° C internal temperature. The average dripping loss of all Good cuts, cooked to 90° C, was 1.0 per cent less than the loss for corresponding Choice cuts. The data showing the wide range in percentages of dripping losses for individual cuts in both Good and Choice cuts are included both in Table 3 and in Figure 2. Analysis of variance of dripping losses showed differences attributable to individual cuts to be significant at the 1 per cent level of

Table 3. Average percentage dripping losses of U. S. Good and U. S. Choice cuts. Muscles from left side cooked to 90° C; those from right side cooked to 90° C and then held in 150° C oven 1 hour longer.

Effect of Treatment	Losses incurred by cooking to 90° C		Losses incurred by cooking to 90° C plus 1 hour holding at 150° C	
Carcass Grade	Good	Choice	Good	Choice
Muscles, left side				
Rectus femoris	25.7	23.4		
Semitendinosus	12.2	11.8		
Biceps femoris, upper	11.9	11.1		
Biceps femoris, middle	15.9	11.9		
Biceps femoris, lower	10.9	15.2		
Vastus lateralis	16.7	18.6		
Semimembranosus, upper	18.9	19.4		
Semimembranosus, lower	23.4	20.4		
Adductor	23.2	22.5		
Average of all cuts	17.6	17.1		
Muscles, right side				
Rectus femoris	25.7	26.4	16.6	19.1
Semitendinosus	11.8	13.0	5.9	6.4
Biceps femoris, upper	10.2	11.4	4.0	7.3
Biceps femoris, middle	14.3	13.3	11.4	11.0
Biceps femoris, lower	12.3	16.6	4.2	10.8
Vastus lateralis	13.0	16.9	10.3	11.7
Semimembranosus, upper	19.2	18.2	15.7	15.0
Semimembranosus, lower	6.4	18.4	5.8	15.4
Adductor	22.3	22.4	19.7	21.0
Average of all cuts	15.0	17.4	10.4	13.1

Plus done

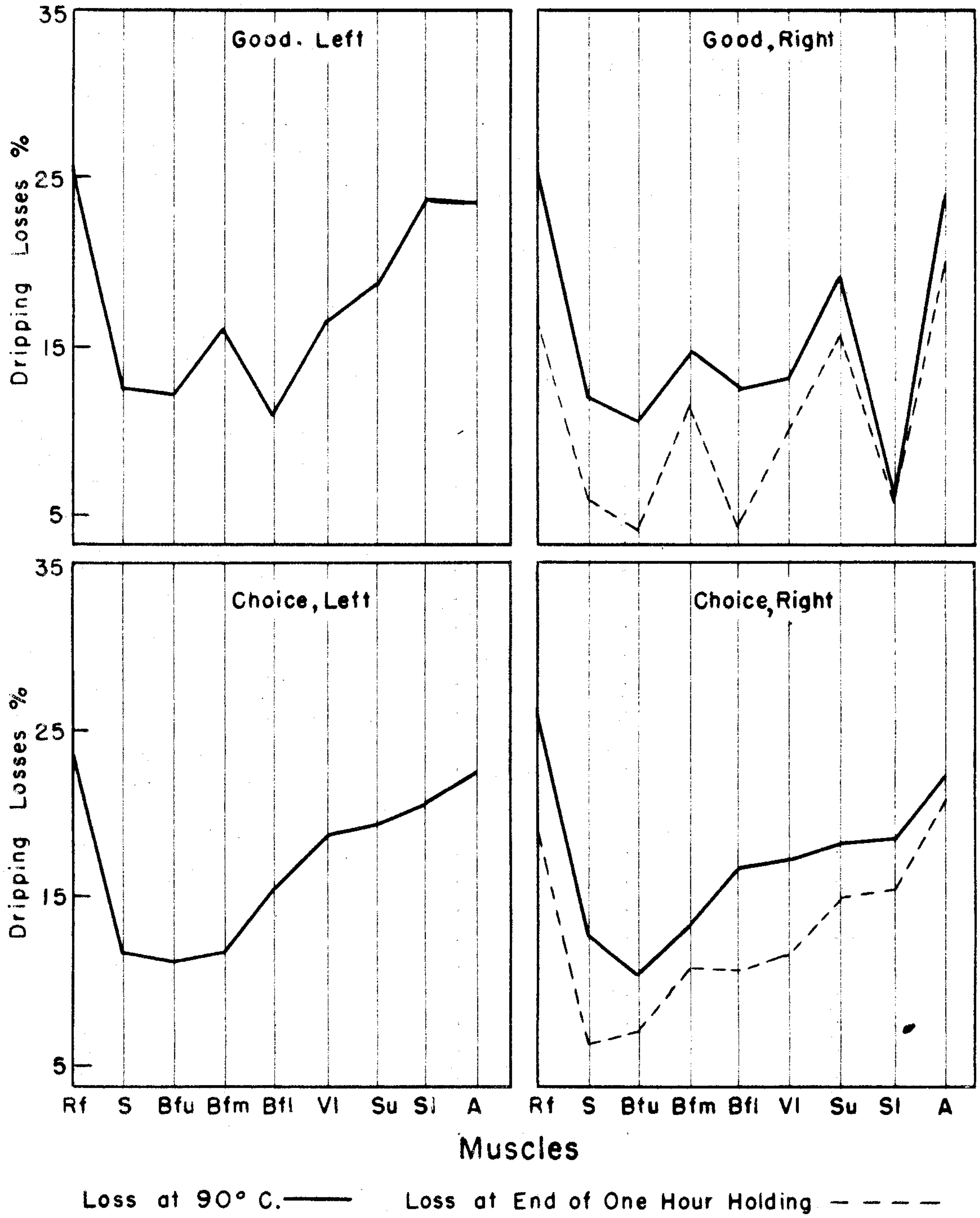


Figure 2. Average Dripping Losses. Space between solid and dotted lines represents decrease of drippings during the one hour holding period after the pot roasts reached 90° C internal temperature.

probability. The rectus femoris and adductor muscles had the highest dripping losses, whereas the dripping losses of the semitendinosus and upper biceps femoris were consistently lowest.

Continued heating of the pot roasts for an hour after they had reached an internal temperature of 90° C caused considerable evaporation of dripping losses. Evaporation of drippings in several instances was so great that nothing remained in the kettles at the end of the cooking period except a charred residue which was unfit for use in sauces or gravies. The relative decrease in the percentage of drippings during the additional hour of holding was almost the same for cuts from both grades of rounds.

Volatile losses

Average volatile losses, as shown in Table 4, did not vary as markedly between Choice and Good grades as among cuts of the same grade. An average of volatile losses for all Good cuts, cooked to 90° C internal temperature, was 1.5 per cent higher than the average for comparable Choice cuts. The range of average volatile losses was 10.9 to 34.0 per cent for Good cuts and 11.3 to 22.0 per cent for Choice cuts cooked to an internal temperature of 90° C.

Average volatile losses for cuts which had been held an additional hour after they had reached 90° C, were 4.1 per cent greater for Good cuts than for comparable Choice cuts. During the holding period volatile losses increased 9.0 per cent for Good cuts and 8.6 per cent for Choice cuts. The data showing the percentage of volatile losses incurred for all pot roasts at an internal temperature of 90° C and also the increased losses incurred during the holding period for pot roasts which were held

Table 4. Average percentage volatile losses of U. S. Good and U. S. Choice cuts. Muscles from left side cooked to 90° C; those from right side cooked to 90° C and then held in 150° C oven 1 hour longer.

Effect of Treatment	Losses incurred by cooking to 90° C		Losses incurred by cooking to 90° C plus 1 hour holding at 150° C	
Carcass Grade	Good	Choice	Good	Choice
Muscles, left side				
Rectus femoris	13.0	13.6		
Semitendinosus	17.6	19.1		
Biceps femoris, upper	20.9	21.9		
Biceps femoris, middle	18.3	22.0		
Biceps femoris, lower	21.9	14.9		
Vastus lateralis	18.5	18.1		
Semimembranosus, upper	17.4	18.3		
Semimembranosus, lower	13.9	16.5		
Adductor	13.6	15.8		
Average of all cuts	17.2	17.8		
Muscles, right side				
Rectus femoris	10.9	11.3	24.2	21.1
Semitendinosus	18.7	17.1	30.8	29.2
Biceps femoris, upper	21.4	18.6	33.0	28.0
Biceps femoris, middle	20.6	19.7	27.8	26.5
Biceps femoris, lower	19.7	14.5	33.5	26.0
Vastus lateralis	23.2	14.3	30.0	25.5
Semimembranosus, upper	18.0	17.8	24.9	23.8
Semimembranosus, lower	34.0	19.8	37.9	25.8
Adductor	14.8	15.5	20.6	19.7
Average of all cuts	20.2	16.5	29.2	25.1

an hour after they reached an internal temperature of 90° C are given in Figure 3.

Fat losses

Fat losses among the individual cuts did not appear to follow any consistent pattern. Differences in the amount of external fat covering of the individual cuts seemed to affect the amount of fat loss more than differences in the amount of fat on the cuts attributable to carcass grade. (Appendix A, 13). The average of fat losses for cuts held an additional hour after they had reached 90° C internal temperature were 1.5 per cent greater for Choice cuts than for corresponding Good cuts. Although care was taken to trim corresponding cuts alike, it is impossible to do this with complete precision. Therefore, differences in trimming must be considered as a variable in interpreting the data on fat losses of the cooked cuts.

Volume losses

Volume losses during the cooking process followed the pattern of total cooking weight losses closely.

During the early stages of cooking, marked changes in the appearance of the cuts were noted. In general, these changes were characterized by shrinkage in the length and width of the cuts with an accompanying thickening of the muscle. With continued cooking, the thickening of the fibers decreased. By the time an internal temperature of 90° C had been reached, the volume and all dimensions of the cuts had decreased markedly.

For cuts cooked to an internal temperature of 90° C the average volume loss for Good cuts was 0.7 per cent greater than the average volume loss for comparable Choice cuts. For pot roasts held 1 hour after they

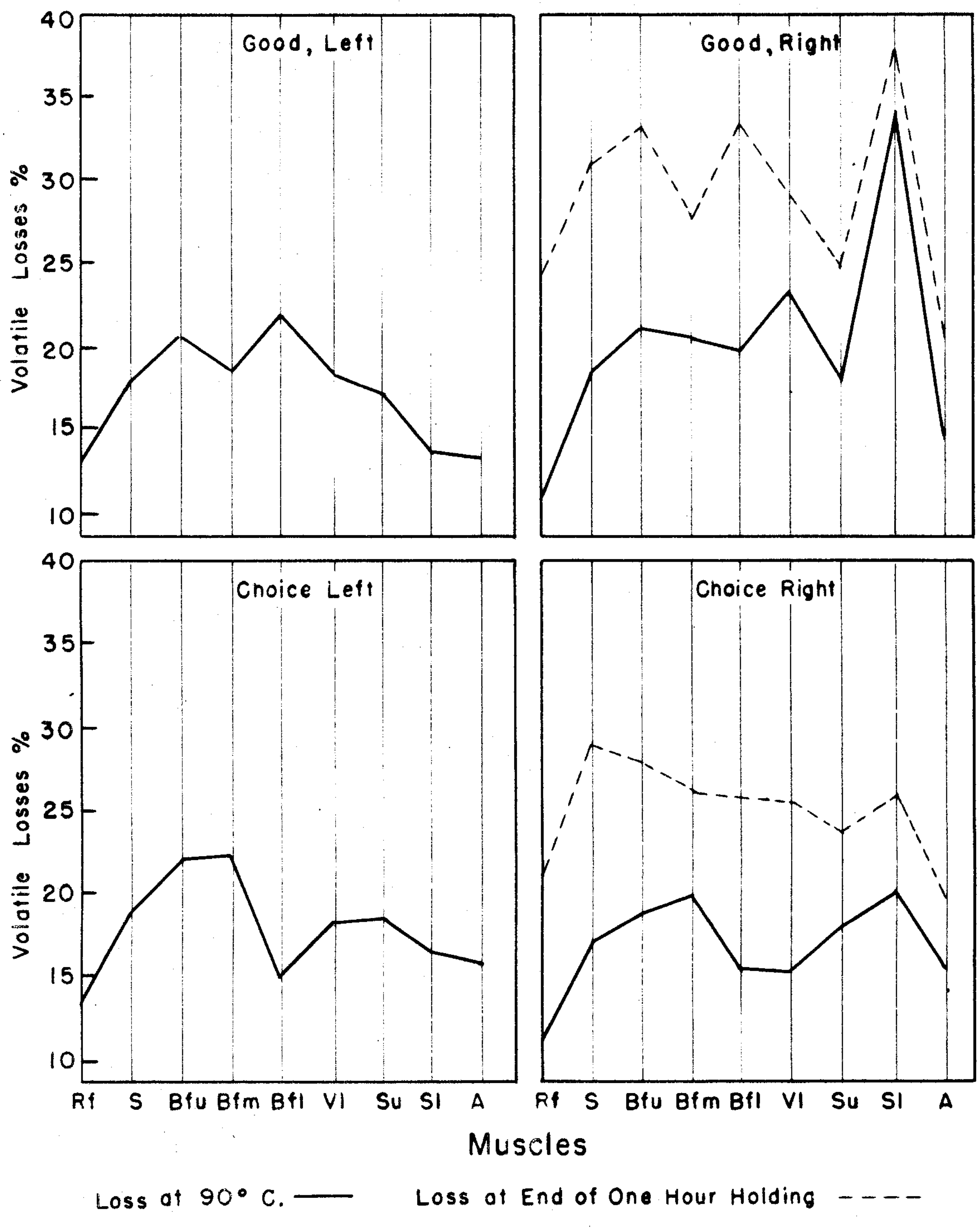


Figure 3. Average Volatile Losses. Space between solid and dotted lines represents additional loss during the one hour holding period after the pot roasts reached 90° C internal temperature.

had reached 90° C, the average volume loss for Good cuts was 1.8 per cent higher than for the corresponding Choice cuts. During the hour of holding, the average volume losses increased 9.5 per cent for Good cuts and 7.8 per cent for comparable Choice cuts. The data for the average volume losses of individual cuts from the two pairs of Choice and the two pairs of Good rounds are shown in Table 5 and in Figure 4. Excessive volume shrinkage occurred simultaneously with high cooking weight losses. Although the rate of shrinkage was slower in the holding period after the pot roasts had reached 90° C internal temperature than during the early stages of cookery, there was sufficient volume loss during the extra hour to indicate that overcooking is a practice to be carefully avoided.

Palatability Factors

Aroma and flavor

Aroma and flavor of cooked meat constitute an important part of its acceptability for food. Cooked meats have characteristic odors and flavors which result from the breakdown of the various constituents of the structural and muscle fiber and cleavage of the fatty tissues during the cooking process. The flavor and aroma of meats cooked to the rare stage apparently retain many characteristics of raw muscle. These rare meats are characterized by slightly salty and faintly acid tastes. When meats are cooked for longer periods of time, however, these mild flavors give way to stronger ones. As the degree of doneness of the meat increases, the sulfury and bitter flavors become more and more pronounced. In the overcooked product or in meats cooked at very high temperatures, disagreeable odors and tastes develop which result from the breakdown of the sulfur

Table 5. Average percentage volume losses of U. S. Good and U. S. Choice cuts. Muscles from left side cooked to 90° C; those from right side cooked to 90° C and then held in 150° C oven 1 hour longer.

Effect of Treatment	Losses incurred by cooking to 90° C		Losses incurred by cooking to 90° C plus 1 hour holding at 150° C	
Carcass Grade	Good	Choice	Good	Choice
Muscles, left side				
Rectus femoris	28.9	19.4		
Semitendinosus	8.7	11.7		
Biceps femoris, upper	20.6	17.8		
Biceps femoris, middle	21.5	18.8		
Biceps femoris, lower	22.4	13.8		
Vastus lateralis	23.1	25.0		
Semimembranosus, upper	23.7	27.3		
Semimembranosus, lower	24.0	25.7		
Adductor	27.4	28.9		
Average of all cuts	22.3	20.9		
Muscles, right side				
Rectus femoris	22.3	17.6	32.4	28.5
Semitendinosus	5.9	12.1	16.4	13.8
Biceps femoris, upper	9.7	6.6	19.2	16.6
Biceps femoris, middle	11.4	16.4	25.2	21.9
Biceps femoris, lower	12.9	12.5	26.8	27.1
Vastus lateralis	21.3	14.9	27.6	24.5
Semimembranosus, upper	22.5	23.6	27.7	26.5
Semimembranosus, lower	21.5	22.1	32.1	28.4
Adductor	22.5	23.8	28.4	31.4
Average of all cuts	16.7	16.6	26.2	24.4

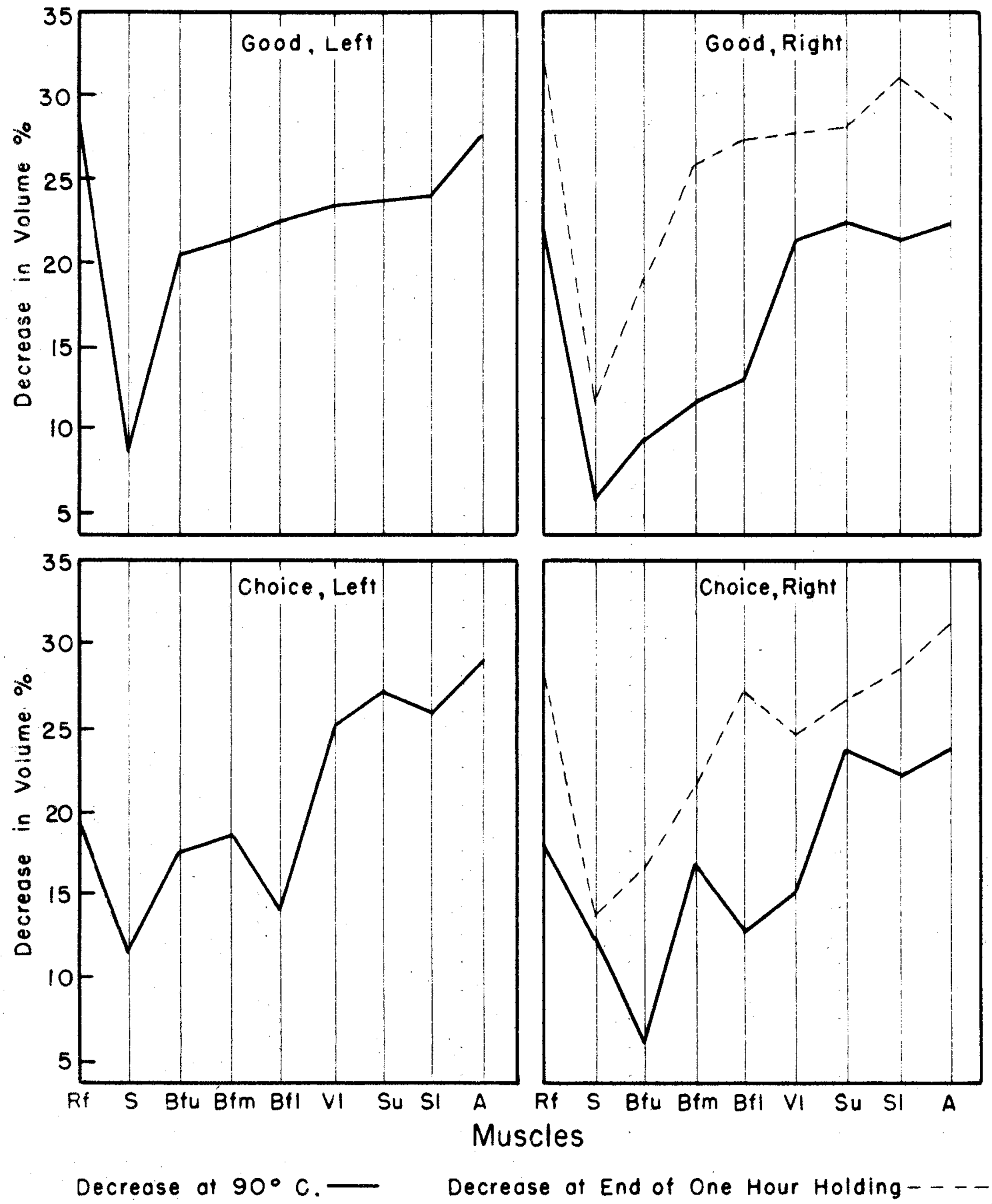


Figure 4. Average Volume Losses. Space between solid and dotted lines represents additional volume losses during the hour holding period after the pot roasts reached 90° C internal temperature.

bearing amino acids in the muscle and connective tissues. Marked deterioration was noted in odor and flavor of cuts cooked an additional hour after reaching 90° C internal temperature.

Comparison of average aroma scores of the four judges, Table 6 and Figure 5, showed no consistent preference between Choice and Good grade cuts. Variation of average scores for aroma showed a range of 6.4 to 7.4 for Good grade and of 5.8 to 7.4 for Choice grade cuts cooked to 90° C internal temperature. Average aroma scores for pot roasts held an hour after reaching an internal temperature of 90° C showed no consistent difference in relative desirability of Good and Choice grade beef. Average aroma scores, shown graphically in Figure 6, for pot roasts held at 150° C for an hour after reaching 90° C internal temperature were slightly lower than for corresponding cuts cooked only to 90° C.

Flavor scores, recorded in Table 6 and Figure 5, showed no difference between desirability of Good and Choice grades cooked to 90° C. Neither did flavor scores for pot roasts cooked to 90° C and held an hour show any preference for grade. Average flavor scores for both Choice and Good grades showed marked deterioration during the holding period of an additional hour after the cuts had reached 90° C internal temperature (Figure 6). The average drop in scores for cuts with the additional holding period was 1.2 points for Good grade and 1.1 points for Choice grade. This was a drop of approximately 15 per cent below scores given the paired samples cooked only to 90° C.

Statistical analysis of aroma scores indicated variations in aroma might be partly attributable to individual animal differences. The F value for differences in aroma scores attributable to muscles was also

Table 6. Average palatability scores: aroma and flavor of cuts from U. S. Choice and U. S. Good beef rounds.

Palatability Characteristic	Aroma		Flavor	
Carcass Grade	Good	Choice	Good	Choice
Cuts cooked to 90° C Internal Temperature				
Rectus femoris	6.9	6.8	5.8	5.7
Semitendinosus	7.3	7.4	6.3	7.2
Biceps femoris, upper	7.4	7.2	6.2	6.3
Biceps femoris, middle	6.9	7.4	6.3	5.9
Biceps femoris, lower	7.3	7.4	6.3	6.6
Vastus lateralis	6.8	5.8	5.6	5.3
Semimembranosus, upper	6.6	7.4	5.7	6.2
Semimembranosus, lower	6.4	6.5	5.2	4.7
Adductor	7.3	7.2	5.4	5.3
Average of all cuts	7.0	7.0	5.9	5.9
Cuts cooked to 90° C Internal Temperature plus one hour additional cooking at 150° C				
Rectus femoris	6.8	6.9	4.5	5.2
Semitendinosus	7.3	7.4	6.0	5.5
Biceps femoris, upper	6.3	6.7	4.9	5.0
Biceps femoris, middle	6.2	6.9	5.0	5.2
Biceps femoris, lower	6.7	6.7	4.9	4.9
Vastus lateralis	6.2	5.9	4.5	4.3
Semimembranosus, upper	6.4	6.4	4.7	5.1
Semimembranosus, lower	4.6	5.5	3.0	3.9
Adductor	6.2	6.2	4.6	4.5
Average of all cuts	6.3	6.5	4.7	4.8

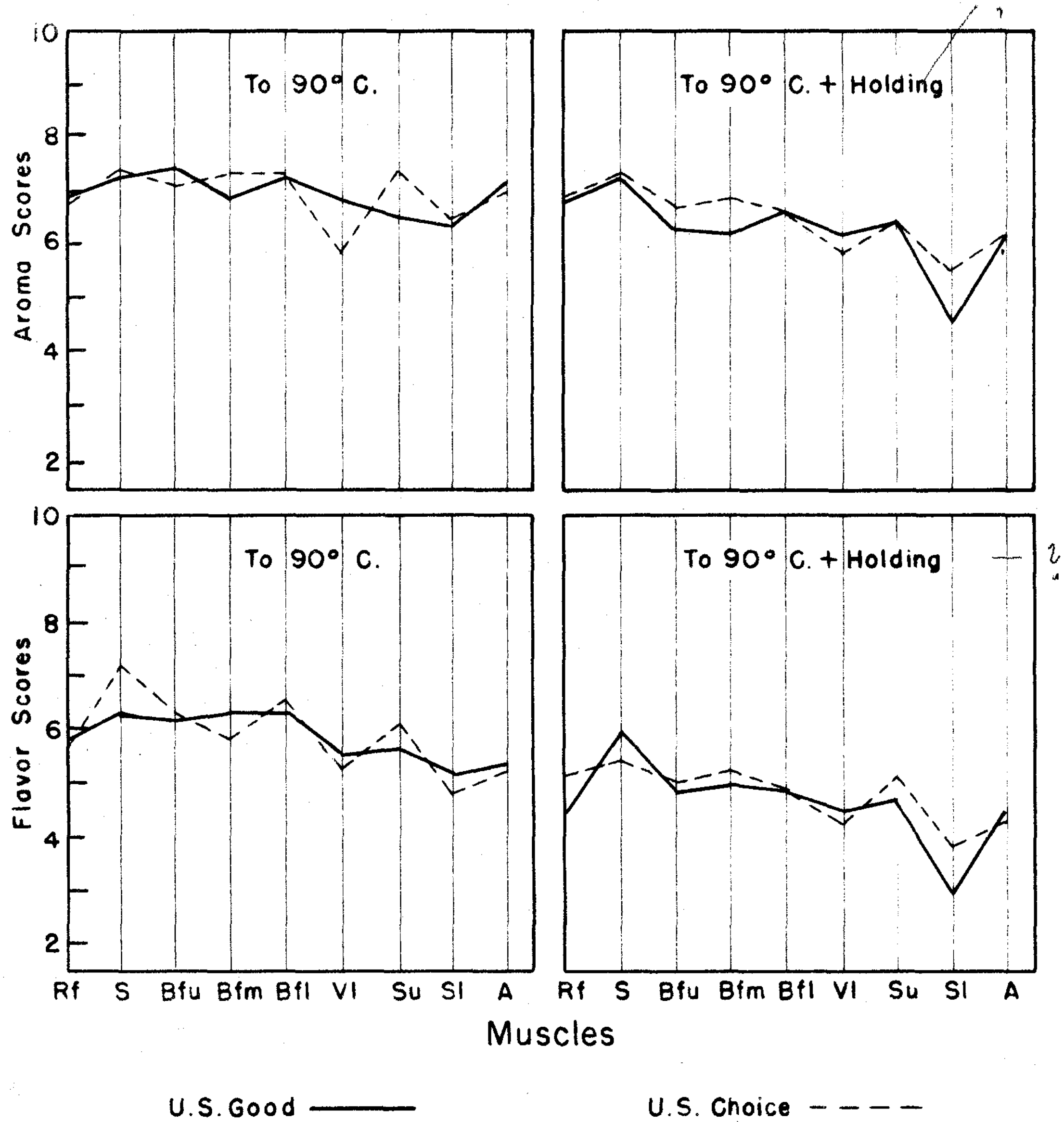
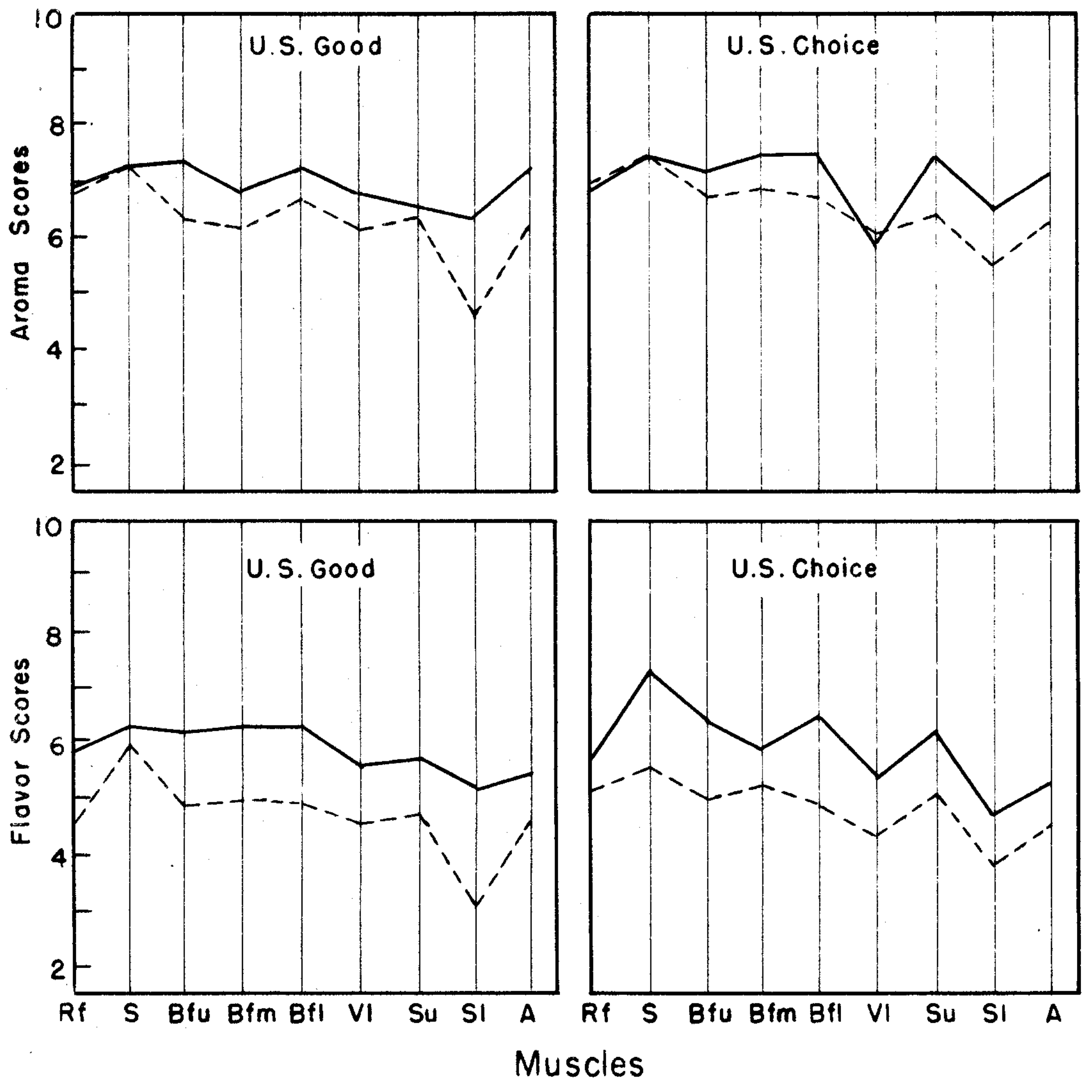


Figure 5. Average Aroma and Flavor Scores. Scores for corresponding cuts of U. S. Choice and U. S. Good grade beef rounds.



Scores for Roasts Cooked to 90° C. ——— To 90° C. + Holding - - - -

Figure 6. Average aroma and Flavor Scores, Showing Effect of Cooking treatment. Space between solid and dotted lines represents change in scores of corresponding cuts during the one hour holding period after the pot roasts reached 90° C internal temperature.

significant at the 1 per cent level of probability. Cooking treatment had the highest F value of all affecting factors and was significant at the 1 per cent level of probability. The F value for the interrelationship of treatment and muscles showed this factor to be significant at the 5 per cent probability level. Variation of aroma scores attributable to the judges was also found to be significant at the 1 per cent level of probability. Interrelationships between muscles and judges and between treatments and judges were also found to be important sources of variance of aroma scores.

In the statistical analysis of flavor scores, sources of variation appeared to be attributable to differences among individual animals, among animals of the same grade, among individual muscles, between treatments, among judges, and the interrelationship between judges and muscles. The highest F value in the analysis of variance of flavor scores, significant at the 1 per cent level of probability, indicated that differences among the judges was an important source of variation. The F value for treatments was also very large and indicated that differences in flavor scores attributable to cooking treatment were also highly significant.

Appearance and texture

The external appearance of the two grades of pot roasts was very similar in all respects. The cuts of both grades were nicely browned on all surfaces although no searing treatment was used. Color of the pot roasts cooked to 90° C internal temperature ranged from medium brown to deep red-brown.

The cuts which were held an additional hour after they had reached 90° C internal temperature were darker and less attractive in appearance than the corresponding cuts cooked just to 90° C. Cuts from both Choice and Good grade rounds which did not have a heavy external covering of fat had a dry and badly shrunken appearance. The cuts which did have a heavy fat covering were sticky to touch after the additional hour of cooking. The fat layer on these cuts was yellow-brown in color and almost translucent.

The appearance of the drippings was objectively evaluated by comparing color and flocculent sediment of the drippings in graduated cylinders. No consistent difference was perceptible between the grades in the color or in the amount of sediment in the drippings for the cuts cooked in like manner. The color of the drippings from the vastus lateralis and adductor muscles cooked to an internal temperature of 90° C was noticeably lighter than the drippings from the other cuts in both grades. The drippings for all cuts were greatly darkened when the cuts were cooked the additional hour after they had reached 90° C internal temperature. The prolonged period required for the Good lower semimembranosus cuts to reach 90° C resulted in excessive evaporation and charring of the drippings of these cuts before the end of the additional holding period.

In the cuts which were cooked an additional hour after they had reached 90° C internal temperature, marked separation of the muscle fibers was noted. The extensive conversion of collagen to gelatin during this holding period apparently was responsible for the tendency of the fibers to fall apart.

From the average appearance scores no consistent difference was noted in favor of Good or Choice grade cuts cooked to 90° C or between the grades for cuts cooked an additional hour after reaching 90° C. See

Table 7 and Figure 7. However, average scores for the cuts held the additional hour after they reached 90° C internal temperature showed a drop of 1.2 points for Good grade and 0.9 point for Choice grade below average scores for comparable cuts cooked only to 90° C internal temperature. The deterioration of appearance of the pot roasts during the extra hour of holding is shown graphically in Figure 8. Among the most pronounced changes in appearance which occurred during the holding period was the marked darkening of large areas on the surface of the sliced muscles. These splotches were dark brown or dark grayish brown. Large areas of the slices also became highly iridescent after exposure to the air. Fiber ends appeared fuzzy and dry in the cut sections of the muscles which had undergone the extra cooking period.

Sources of variation in appearance scores, as determined by analysis of variance, included treatment, judges, muscles, individual animals, and interrelationships of these factors. The F value for grade was non-significant.

The average texture score for all Choice cuts cooked to 90° C internal temperature was exactly the same as for corresponding Good cuts cooked in the same way. Average texture scores for cuts held an additional hour after reaching 90° C were also the same for both grades and showed only a drop of 0.2 point below scores of the cuts cooked just to 90° C internal temperature. Texture scores are shown in Table 7, and the graphic representation of texture scores for the two grades is included in Figure 7.

The analysis of variance for texture scores showed that the differences among individual muscles and also among the judges and the

Table 7. Average palatability scores: appearance and texture of cuts from U. S. Choice and U. S. Good beef rounds.

Palatability Characteristic	Appearance		Texture	
Carcass Grade	Good	Choice	Good	Choice
Cuts cooked to 90° C Internal Temperature				
Rectus femoris	6.3	6.1	6.0	5.9
Semitendinosus	8.2	7.8	7.4	7.2
Biceps femoris, upper	6.7	6.9	6.4	6.4
Biceps femoris, middle	6.6	6.8	4.8	4.7
Biceps femoris, lower	6.3	6.7	5.4	6.2
Vastus lateralis	6.0	5.8	6.2	6.2
Semimembranosus, upper	7.0	7.6	7.2	7.3
Semimembranosus, lower	5.9	6.1	3.9	4.2
Adductor	6.7	6.5	6.7	5.6
Average of all cuts	6.6	6.7	6.0	6.0
Cuts cooked to 90° C Internal Temperature plus one hour additional cooking at 150° C				
Rectus femoris	6.2	6.3	6.4	6.4
Semitendinosus	7.0	6.6	6.9	6.9
Biceps femoris, upper	5.1	5.3	6.6	6.2
Biceps femoris, middle	5.6	5.7	5.2	4.7
Biceps femoris, lower	4.9	5.6	5.6	5.8
Vastus lateralis	5.1	5.4	5.3	5.4
Semimembranosus, upper	5.0	6.5	6.6	7.3
Semimembranosus, lower	4.5	5.0	3.4	3.9
Adductor	5.4	5.9	5.9	5.8
Average of all cuts	5.4	5.8	5.8	5.8

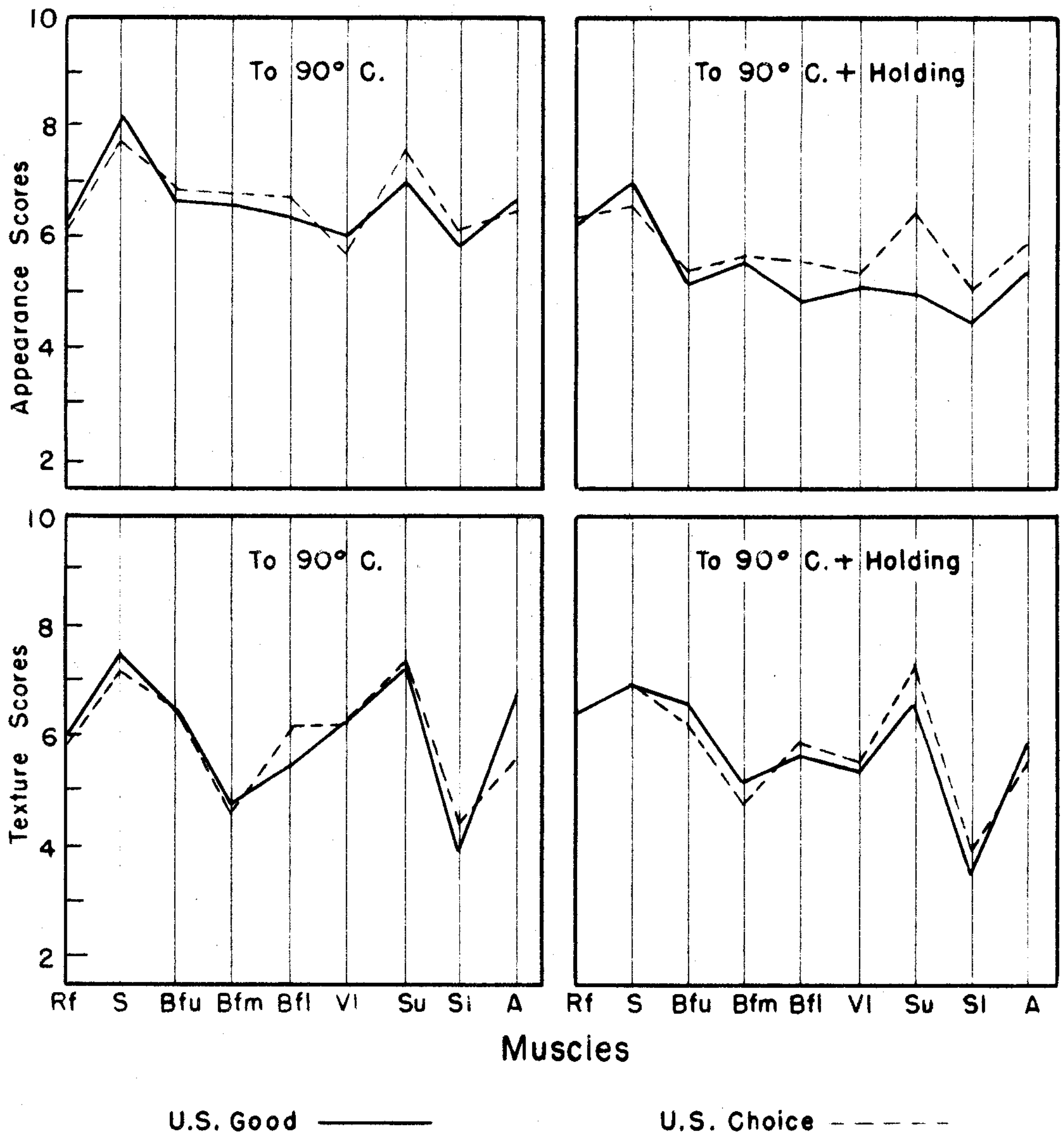


Figure 7. Average Appearance and Texture Scores. Scores for corresponding cuts of U. S. Choice and U. S. Good grade beef rounds.

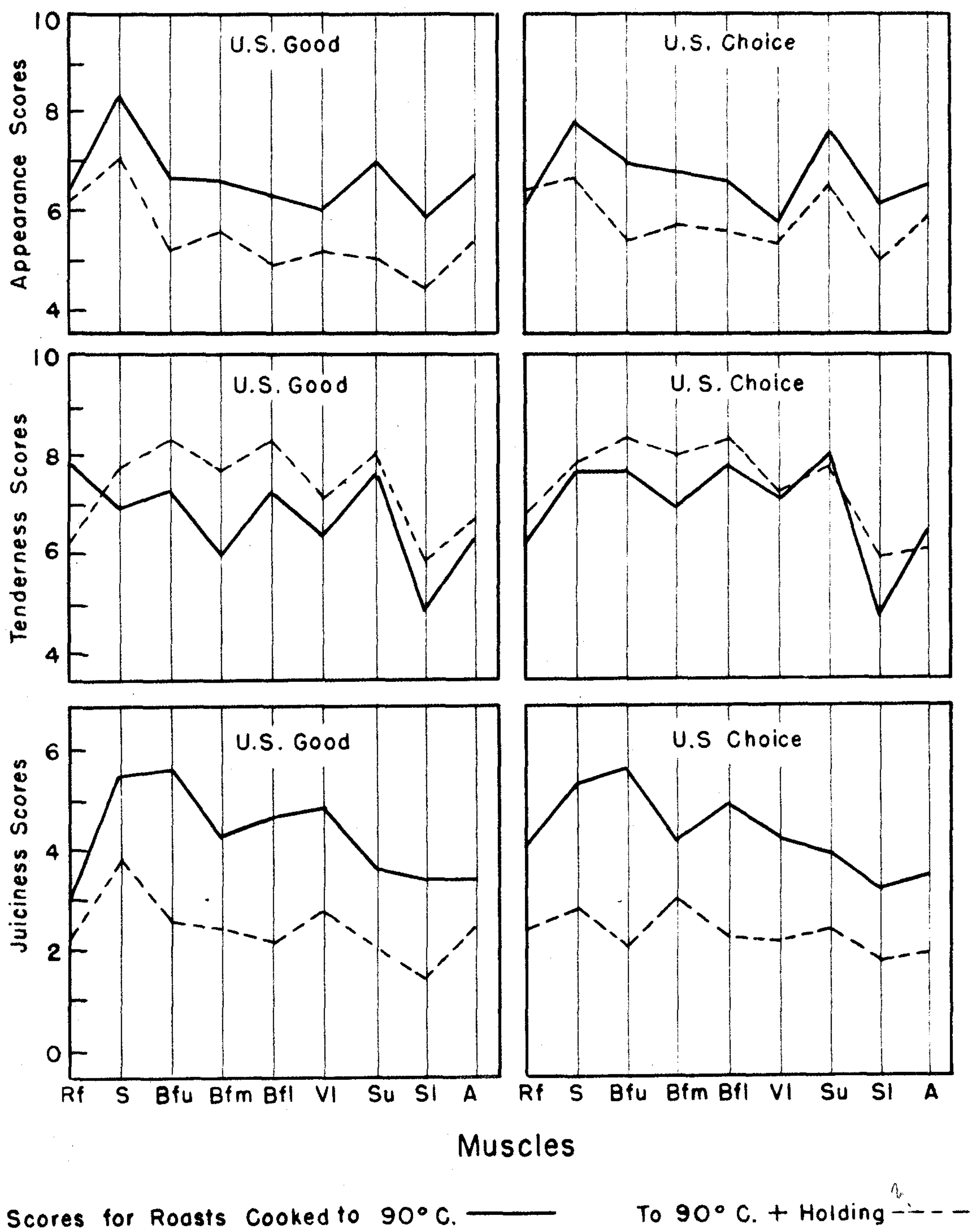


Figure 8. Average Scores for Appearance, Tenderness and Juiciness Showing the Effect of Cooking Treatment. Space between solid and dotted lines represents change in scores of corresponding cuts during the one hour holding period after the pot roasts reached 90° C internal temperature.

interrelationship between these two factors were the most obvious sources of variance. All of these factors were significant at the 1 per cent level of probability. Sources of variation in texture scores which were significant at the 5 per cent level included variation in the individual animals and among animals of the same grade. Neither grade of carcass nor cooking treatment had significant F values in the analysis of variance of texture scores.

Tenderness

From comparison of the average tenderness scores and of the average shear force readings of the Good and Choice cuts cooked to 90° C internal temperature, it appeared that there was no important difference in tenderness between the two grades. As indicated in Table 8 and Figure 9, the corresponding muscles from the two grades, cooked by both methods, followed the same pattern of relative tenderness, with the exception of the Good grade rectus femoris cooked to 90° C internal temperature.

A slight tenderizing effect of the additional hour of cooking after the pot roasts reached an internal temperature of 90° C was evident both in the scores of the judges and in the shear force readings. As may be noted in Figure 9, there was a very close relationship between the subjective tenderness test, indicated by the scores of the judges, and the objective test for tenderness, indicated by the shear force readings. In evaluating these methods for determining tenderness, the following negative correlations were found between the tenderness scores and pounds shear force.

Table 8. Average tenderness scores and shear force readings of cuts from U. S. Choice and U. S. Good beef rounds.

Tenderness Evaluation	Scores		Pounds Shear Force	
Carcass Grade	Good	Choice	Good	Choice
Cuts cooked to 90° C Internal Temperature				
Rectus femoris	7.8	6.3	15.3	11.9
Semitendinosus	7.0	7.7	18.7	15.4
Biceps femoris, upper	7.4	7.7	11.4	9.9
Biceps femoris, middle	6.0	7.0	17.7	15.5
Biceps femoris, lower	7.4	7.8	11.5	10.7
Vastus lateralis	6.4	7.2	15.0	18.1
Semimembranosus, upper	7.7	8.1	10.4	15.5
Semimembranosus, lower	4.9	4.8	26.0	27.8
Adductor	6.4	6.6	23.2	22.7
Average of all cuts	6.8	7.0	16.6	16.4
Cuts cooked to 90° C Internal Temperature plus one hour additional cooking at 150° C				
Rectus femoris	6.3	6.8	13.7	7.3
Semitendinosus	7.8	8.0	13.9	12.2
Biceps femoris, upper	8.4	8.4	5.6	4.6
Biceps femoris, middle	7.7	8.1	10.9	7.9
Biceps femoris, lower	8.4	8.4	7.2	5.4
Vastus lateralis	7.2	7.3	22.1	14.6
Semimembranosus, upper	8.1	7.9	8.7	9.6
Semimembranosus, lower	5.8	6.0	26.8	23.4
Adductor	6.8	6.2	20.3	21.9
Average of all cuts	7.4	7.5	14.4	11.8

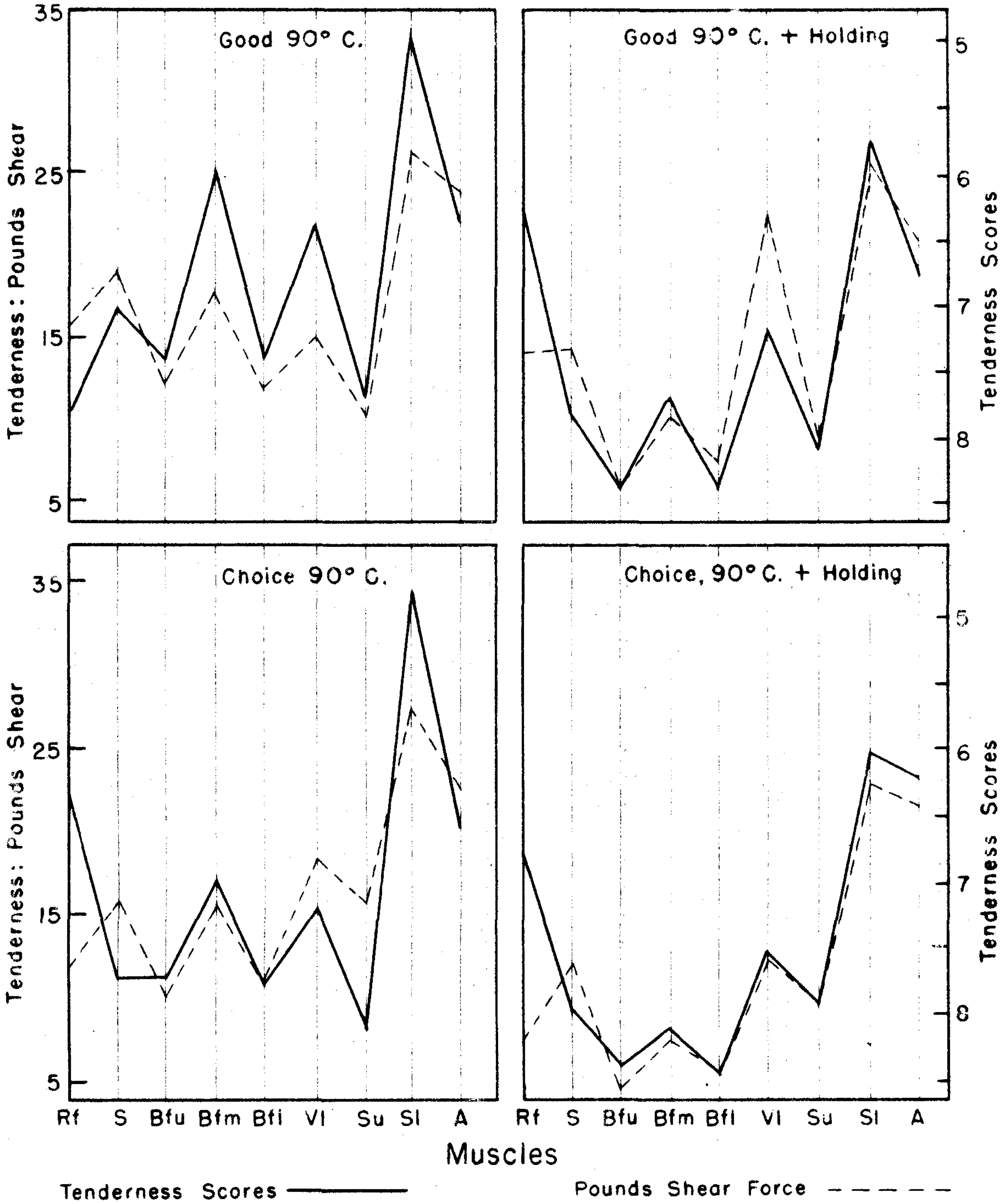


Figure 9. Average Tenderness Ratings. Scores and shear force readings for corresponding cuts of U. S. Choice and U. S. Good grade beef rounds.

Grade	Cooked to 90° C	Held 1 hour after reaching 90° C
Good	r =-.8179**	r =-.8401**
Choice	r =-.7347*	r =-.8493**

From these very high correlations it appeared that the two methods were measuring the same characteristic. Three of the four correlations were significant at the 1 per cent level of probability and the fourth correlation also had a numerical r-value so close to the 1 per cent probability level that it was also highly significant.

Analysis of variance of tenderness scores indicated that cooking treatments, individual muscle differences, and differences attributable to the judges were all important sources of variance. Each of these factors had F values which were significant at the 1 per cent probability level. Interrelationships among these factors were also highly significant as sources of variation in tenderness scores. No significant F values were found for carcass grade or for interrelationship of carcass grade with any other factor.

In the analysis of variance for tenderness, as determined by shear force readings, F values for muscles, treatments, and among animals of the same grade were found to be significant at the 1 per cent level of probability. Individual animal differences were also found to constitute a source of variation, and an F value for this factor was found to be significant at the 5 per cent level of probability. No significant F value was found for carcass grade or the interrelation of carcass grade with any other factor.

The graphic presentation of the tenderizing effect of the extra hour of cooking on the various cuts of Good and Choice beef round is shown in Figure 8. As may be noted in this figure, a slight tenderizing effect generally appeared to result from the holding period after the pot roasts had reached 90° C internal temperature. With the exception of the rectus femoris of Good grade and the upper semimembranosus of Choice grade, this tenderizing effect seemed to be apparent to the scorers. Since the correlation between scores and shear force readings was very high, the tenderizing effect, as indicated by the objective method, was not graphed.

It is obvious that the effect of the slight increase in tenderness, attributable to prolonged cooking, was more than off-set by the deterioration of the other palatability characteristics (Figures 6 and 8). Development of highly undesirable odors and flavors, loss of attractiveness of servings, and marked decrease in juiciness during the extra hour of cooking indicated that the slight increase in tenderness was of relatively little importance to the acceptability of the product.

Juiciness

Differences in juiciness, as determined by the average scores of the judges, were not perceptible between the Choice and Good grades either when the cuts were cooked to 90° C internal temperature or when the cuts were held an additional hour after reaching 90° C.

Juiciness, determined on the basis percentage of press fluid, was practically the same for Choice and Good grade cuts cooked to 90° C internal temperature. When cuts were cooked an additional hour after they had reached 90° C internal temperature, the average press fluid figure for Choice cuts was 2.92 per cent higher than it was for the average of the corresponding Good cuts. (Table 9).

Table 9. Average juiciness scores and percentage press fluid of cuts from U. S. Choice and U. S. Good beef rounds.

Juiciness Evaluation Carcass Grade	Scores Good	 Choice	% Press Fluid Good	 Choice
Cuts cooked to 90° C Internal Temperature				
Rectus femoris	3.0	4.2	31.34	36.12
Semitendinosus	5.6	5.5	38.99	38.77
Biceps femoris, upper	5.7	5.7	38.85	39.41
Biceps femoris, middle	4.3	4.2	35.91	36.00
Biceps femoris, lower	4.7	5.0	33.45	35.77
Vastus lateralis	4.9	4.3	35.63	36.46
Semimembranosus, upper	3.6	4.0	36.57	37.88
Semimembranosus, lower	3.4	3.4	33.40	31.07
Adductor	3.4	3.6	30.47	28.84
Average of all cuts	4.3	4.4	34.96	35.59
Cuts cooked to 90° C Internal Temperature plus one hour additional cooking at 150° C				
Rectus femoris	2.4	2.6	32.80	32.65
Semitendinosus	3.9	2.9	31.43	35.74
Biceps femoris, upper	2.6	2.2	34.95	35.82
Biceps femoris, middle	2.5	3.1	31.25	32.97
Biceps femoris, lower	2.2	2.4	31.79	35.19
Vastus lateralis	2.8	2.3	27.78	34.94
Semimembranosus, upper	2.1	2.4	30.12	32.99
Semimembranosus, lower	1.5	1.9	26.81	27.38
Adductor	2.5	2.0	26.83	32.34
Average of all cuts	2.5	2.4	30.42	33.34

The drying effect of the extra hour of cooking is clearly demonstrated in Figure 8. Samples from the pot roasts cooked for the additional hour were frequently so dry that some judges commented that mastication of the meat was extremely difficult. This lack of juiciness was described by such terms as powdery and excelsior-like. It was frequently reported that these samples were so dry that it was difficult to moisten them sufficiently with saliva to swallow them.

Good correlation was found between the judges' scores for juiciness and the percentage of press fluid in the samples which were cooked to 90° C internal temperature. For these cuts from Good grade rounds, the correlation between the subjective and objective measurements of juiciness was $r = +.8089^{**}$, which was significant at the 1 per cent level of probability. For cuts from Choice grade rounds, cooked to 90° C internal temperature, the correlation between the two methods for determining juiciness was $r = +.7733^{*}$, which was significant at the 5 per cent level of probability. Correlations of the methods of evaluating juiciness were not found to be significant for the either Choice or Good grade when the pot roasts were cooked beyond an internal temperature of 90° C.

The results of the subjective and objective methods for determining juiciness are shown graphically in Figure 10. A definite similarity in pattern may be noted between the two methods in results for pot roasts cooked to 90° C internal temperature. However, great divergence of trends is apparent in the results of the testing of cuts cooked an additional hour after reaching 90° C.

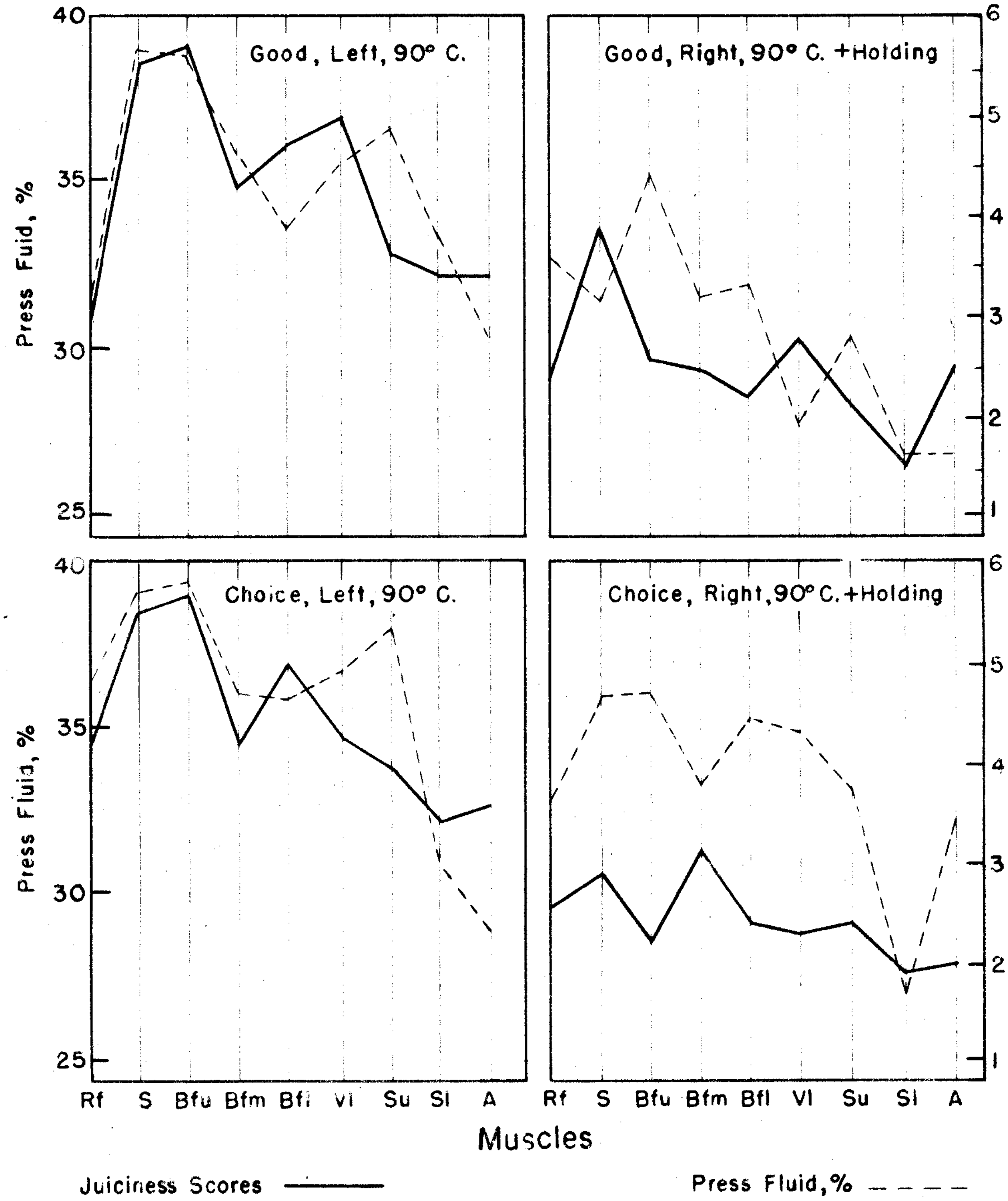


Figure 10. Average Juiciness Ratings. Scores and percentage press fluid for corresponding cuts of U. S. Choice and U. S. Good grade beef rounds.

Edible Portion Cost

The actual portion cost of cooked meats is of the utmost importance to the food service manager who wishes to operate a profitable business. Initial unit cost per pound sometimes gives misleading impressions of economy. In considering the actual portion cost of the cooked meat, one must include not only the initial unit cost but also allowances for bone, shrinkage, waste trim, cooking losses, and fuel cost.

The distribution of weights among the constituent parts of the rounds used in this study is given in Table 10. Shrinkage weight, as recorded here, is the difference between the weight of the rounds at the time of shipping and the weight of the rounds on the day on which they were cut into pot roasts. Bone and waste are figured on the percentage recommended in standard cutting procedures for Chicago Style cutting. Raw weight of the pot roasts is actual weight of the cuts prior to cooking. Edible trim is the difference between the initial weight of the round and the sum of shrinkage, bone and waste, and raw weight of the pot roasts.

In determining the actual unit cost of the meat used for pot roasts, edible trim value was deducted from the cost of the rounds as purchased. This difference was used as the actual cost of the raw meat used for pot roasting from each pair of rounds. The total cost of all uncooked pot roasts for each grade was then divided by the total raw weight of the pot roasts to determine the actual cost per pound of the raw pot roasts. As shown in Table 11, the average cost per pound of raw pot roasts was $0.9069 for Good grade and $0.9509 for Choice grade.

The information from which the per pound cost of the cooked pot

Table 10. Distribution of weight among constituent parts of beef rounds used in study. (Pounds).

Carcass Grade	Animal	Total as Purchased	Shrinkage	Bone & Waste	Edible Trim	Raw Weight Pot Roasts
Good	I	123.00	3.00	20.17	35.71	64.12
	IV	154.00	2.75	26.18	58.38	66.69
	Total	277.00	5.75	46.35	94.09	130.81
Choice	II	139.00	3.50	22.66	47.52	65.32
	III	148.00	1.75	26.05	54.26	65.94
	Total	287.00	5.25	48.71	101.78	131.26

Table 11. Distribution of costs among constituent parts of beef rounds used in study.

Carcass Grade	Animal Number	Wholesale Unit Cost	Initial Cost of Rounds as Purchased	Edible Trim Cost @ \$0.40 Per lb.	~~Cost of~~ Uncooked Pot Roasts	Average Cost per pound, Raw Pot Roasts
Good	I	\$0.5700	\$70.11	\$14.29	\$55.82	
	IV	\$0.5595	86.16	23.35	62.81	
	Total		156.27	37.64	118.63	\$0.9069
Choice	II	\$0.5950	82.71	19.01	63.70	
	III	0.5595	82.81	21.70	61.11	
	Total		165.52	40.71	124.81	0.9509

roasts was determined is shown in Table 12. This figure was obtained by dividing the total cost of the raw cuts of each grade by the total cooked weight of the roasts prepared by each of the methods previously described. From these calculations it was found that of the cuts cooked to 90° C internal temperature the Good grade pot roasts cost $1.4026 per pound and the Choice grade pot roasts cost $1.4731 per pound. The increase in cooking losses during the additional hour of cooking after the pot roasts reached an internal temperature of 90° C resulted in rather sizable increases in the cost per pound of the cooked meat. For the cuts which received the additional hour of cooking the cost of Good grade cooked meat was $1.5081 per pound and of Choice grade $1.5460 per pound. Thus, it appeared that on the basis of cost per pound of cooked weight, the Good grade cuts cooked to 90° C internal temperature were the most economical.

The total cost of the edible portion of the cooked pot roasts, tabulated in Table 13, included the cost of fuel as well as the actual cost of the meat. On the basis of total cost of edible portion, Good grade cuts cooked to 90° C internal temperature averaged $0.0114 less per portion than the corresponding Choice cuts. On the same basis, the Good grade cuts which were cooked an additional hour after reaching 90° C internal temperature averaged $0.0055 less per portion than the corresponding Choice cuts cooked in the same way.

The continued cooking of the cuts after they had reached 90° C resulted in an increase in total cost of $0.0177 per 2.5 ounce portion for Good grade pot roasts and an increase of $0.0118 per portion of Choice grade pot roasts. Although these increases in cost per portion

Table 12. Cooked beef cuts: cost per pound and per portion.

Carcass Grade	Animal	Weight of Raw Cuts, Pounds	Total Cost of Raw Cuts	Weight of Cuts Cooked, Pounds	Cooked Cuts Cost 1 lb.	Cost 2.5 oz Cooked Portion
Cuts Cooked to 90° C Internal Temperature						
Good	I Left	32.61	$29.57	21.33		
	IV Left	33.70	30.56	21.54		
	Total	66.31	60.13	42.87	$1.4026	$0.2192
Choice	II Left	32.27	30.68	20.70		
	III Left	32.23	30.65	20.94		
	Total	64.50	61.34	41.64	1.4731	0.2302
Cuts Cooked to 90° C Internal Temperature Plus One Additional Hour						
Good	I Right	31.51	28.58	19.15		
	IV Right	32.99	29.92	19.64		
	Total	64.50	58.50	38.79	1.5081	0.2356
Choice	II Right	33.05	31.43	20.22		
	III Right	33.71	32.05	20.84		
	Total	66.76	63.48	41.06	1.5460	0.2416

Table 13. Total edible portion cost of U. S. Good and U. S. Choice cuts.

Carcass Grade	Cost of Cuts Pot Roasted	Fuel Cost @ $1.00/500 Cu. Ft.	Total Cost of Pot Roasts	Weight Cooked Roasts, lb.	Total Cost Pound	Total Cost 2.5 oz.
Cuts Cooked to 90° Internal Temperature						
Good	$60.13	$ 1.0250	$ 61.1550	42.87	$ 1.4265	$ .2229
Choice	61.34	1.1068	62.4480	41.64	1.4997	.2343
Cuts Cooked to 90° C Internal Temperature Plus One Additional Hour						
Good	58.50	1.2326	59.7326	38.79	1.5399	.2406
Choice	63.48	1.2076	64.6876	41.06	1.5754	.2461

seem very small, the figure gains significance when viewed from the standpoint of the foods operator. Multiplying the slight increases in portion cost by probable number of portions to be served makes these figures worthy of consideration by food managers concerned with economical operation.

SUMMARY AND CONCLUSIONS

The first objective of this study was the comparison of the palatability characteristics, cooking weight losses, and edible portion cost of cuts from U. S. Choice and U. S. Good beef rounds (1) cooked by moist heat to 90° C and (2) cooked an additional hour after 90° C internal temperature had been reached by the cuts. Grade designations are those of the new federal grading system which became effective on January 1, 1951. A summary of the results of the comparison of the two grades follows.

1. From the scores of the judges it appeared that there was no consistent preference between pot roasts from Choice and Good rounds for flavor, aroma, texture, tenderness, or juiciness. This was true both for pot roasts cooked to an internal temperature of 90° C and for those cooked an additional hour after they reached 90° C internal temperature.
2. Appearance was graded slightly higher by the judges for the Choice cuts than for the Good cuts after the additional holding period of an hour after the cuts reached an internal temperature of 90° C.
3. Average values of the shear test for tenderness indicated that Choice cuts were slightly more tender than Good cuts at the end of the extra hour of cooking.
4. The objective test for juiciness indicated a slightly higher percentage of press fluid in Choice cuts than in

Good cuts for pot roasts cooked an additional hour after they had reached an internal temperature of 90° C.

5. There was no significant difference in the amount of total cooking weight losses between the different grades cooked by either of the methods. Average dripping losses were slightly higher for Choice cuts than for Good cuts regardless of the cooking method. Average volatile losses were somewhat higher for Good grade cuts than for Choice grade cuts cooked by either method.
6. Greater differences were noted among the individual cuts from the same round than were noted between the two grades for average percentage of cooking losses and average palatability scores.
7. The 2.5 ounce edible portion for Choice cuts cost \$0.0114 more than for Good cuts cooked to 90° C. The 2.5 ounce edible portion from Choice cuts, cooked an hour after they reached an internal temperature of 90° C, cost \$0.0055 more than the 2.5 ounce portion from comparable Good grade cuts.

The second objective of the study was the consideration of the effect of extent of cooking on palatability characteristics, cooking weight losses, and edible portion cost. The results of the comparison of pot roasts cooked to an internal temperature of 90° C with those cooked to 90° C and then held an additional hour at 150° C follow.

1. The palatability scores of the judges showed that there was marked deterioration of aroma, flavor, juiciness, and

appearance in samples of both Good and Choice grades which were cooked an additional hour after they reached an internal temperature of 90° C.

2. Tenderness, evaluated both from the scores of the judges and from shear tests, increased somewhat for cuts from both grades when the cooking was continued for an hour after the internal temperature of the cuts reached 90° C.
3. From the analysis of variance of scores for the palatability characteristics it was found that the effect of cooking treatment was significant at the 1 per cent level of probability for aroma, flavor, juiciness, appearance, and tenderness. The F value for treatment as a source of variance in texture scores was not significant.
4. Total cooking weight losses during the additional hour of holding at 150° C increased 4.4 per cent for Good cuts and 4.3 per cent for Choice cuts. During this period volatile losses increased markedly and total dripping losses decreased.
5. The cost of a 2.5 ounce portion of Good grade cuts increased $0.0177 when the cooking period was extended an hour beyond the time at which the pot roasts had an internal temperature of 90° C. The additional hour of cooking increased cost of Choice grade cuts $0.0118 per portion.

From the findings of this study the following conclusions were drawn.

1. U. S. Good grade beef rounds, prepared by pot roasting as described in this study, compare favorably with U. S. Choice

in eating quality and offer an opportunity for some savings in purchasing. Since there was no significant difference found in the total cooking losses between the two grades, the differences in final edible portion cost appear to be chiefly attributable to the differences in the initial unit cost of the uncooked cuts.

2. Continued cooking of the pot roasts of both Good and Choice beef rounds in this study, after they had reached an internal temperature of 90° C, resulted in a marked deterioration of aroma, flavor, juiciness, and appearance. The longer cooking period had a slight tenderizing effect on both Good and Choice cuts. However, this tenderizing effect was more than off-set by the accompanying loss of juiciness and appearance and the development of undesirable flavors and odors. This longer cooking period, which resulted in additional total cooking losses of 4.4 per cent for Good and 4.3 per cent for Choice pot roasts, brought about marked losses in palatability and also increased the cost of edible portion for both grades of meat.

LITERATURE CITED

1. Alexander, L. M. and Clark, N. G. Shrinkage and heat penetration during roasting of lamb and mutton as influenced by carcass grade, ripening period, and cooking methods. U. S. Dept. Agr. Tech. Bul. 440. 1934.

2. Alexander, L. M. and Clark, N. G. 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. Tech. Bul. 676. 1939.

3. Barbella, N. G., Hankins, O. G., and Alexander, L. M. The influence of retarded growth of lambs on flavor and other characteristics of the meat. Proc. Am. Soc. Animal Prod. 29: 289-294. 1936.

4. Barbella, N. G., Tanner, B., and Johnson, T. G. Relationships of flavor and juiciness of beef to fatness and other factors. Proc. Am. Soc. Animal Prod. 32: 320-325. 1939.

5. Bate-Smith, E. C. Organoleptic tests in the food industry. I. General introduction and quality of animal products. J. Soc. Chem. Ind. 68: 78-80. 1949.

6. Bendall, J. R. Effect of cooking on the creatine-creatinine, phosphorus, nitrogen, and pH values of raw, lean beef. J. Soc. Chem. Ind. 65: 226-230. 1946.

7. Bengtsson, K. and Helm, E. Principles of taste testings. Wallerstein Lab. Communications 9, no. 28: 171-180. 1946.

8. Beuk, J. F., Chornock, F. W., and Rice, E. E. The effect of severe heat treatment upon the amino acids of fresh and cured pork. J. Biol. Chem. 175: 291-297. 1948.

9. Bouthilet, R. J. A note on the nature of flavor constituents from poultry meat. Food Tech. 3: 118. 1936.

10. Brady, D. E. A study of the factors influencing tenderness and texture of beef. Proc. Am. Soc. Animal Prod. 30: 246-249. 1937.

11. Brady, D. E., Peterson, W. J., and Shaw, A. O. Riboflavin and thiamin contents of pork loin muscles and their retention during cooking. Food Res. 9: 400-405. 1944.

12. Brannaman, G. A., Hankins, O. G., and Alexander, L. M. The relation of degree of finish in cattle to production and meat flavors. Proc. Am. Soc. Animal Prod. 29: 295-300. 1936.

13. Burr, G. O., Lundberg, W. O., and Chipault, J. R. The role of various substances in stabilizing animal tissue. Oil and Soap 23: 382-384. 1946.

14. Child, A. M. and Baldelli, M. Press fluid from heated beef muscle. J. Agr. Res. 48: 1127-1134. 1934.

15. Child, A. M. and Fogarty, J. A. Effect of interior temperatures of beef muscle upon press fluid and cooking losses. J. Agr. Res. 51: 655-662. 1935.

16. Child, A. M. and Moyer, E. Z. Variations in sampling beef and pork roasts for press fluid investigation. Food Res. 3: 305-312. 1938.

17. Child, A. M. and Sartorius, M. J. Effect of exterior temperature upon press fluid, shear force, and cooking losses of roasted beef and pork muscles. J. Agr. Res. 57: 865-871. 1938.

18. Cline, J. A., Trowbridge, E. A., and Foster, M. T. How certain methods of cooking affect the quality and palatability of beef. Mo. Agr. Expt. Sta. Bul. 293. 1930.

19. Cover, S. The effect of temperature and time of cooking on the tenderness of roasts. Texas Agr. Expt. Sta. Bul. 542. 1937.

20. Cover, S., Dilsaver, E. M., and Hayes, R. M. Retention of the B vitamins in beef and lamb after stewing. III. Pantothenic acid. J. Am. Diet. Assn. 23: 693-697. 1947.

21. Cover, S., Dilsaver, E. M., and Hayes, R. M. Retention of the B vitamins in beef and lamb after stewing. IV. Niacin. J. Am. Diet. Assn. 23: 769-772. 1947.

22. Cover, S., Dilsaver, E. M., and Hayes, R. M. Retention of the B vitamins after large-scale cooking of meat. I. Suitability of left and right muscles for retention studies. Food Res. 13: 472-474. 1948.

23. Cover, S., Dilsaver, E. M., Hayes, R. M., and Smith, W. H. Retention of the B vitamins after large-scale cooking of meat. II. Roasting by two methods. J. Am. Diet. Assn. 25: 949-951. 1949.

24. Crist, J. W. and Seaton, H. L. Reliability of organoleptic tests. Food Res. 6: 529-536. 1941.

25. Crocker, E. C. Flavor of meat. [Editorial] Food Res. 13: 179-183 1948.

26. Crocker, E. C. and Platt, W. Food flavors: a critical review of recent literature. Food Res. 2: 183-186. 1947.

27. Dean, J. B. Effect of cooking on tenderness of meat. I. A comparison of two cooking temperatures on paired tough cuts, cooked by moist heat in the oven. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1933.

28. Dove, W. F. Food acceptability: its determination and evaluation. Food Tech. 1: 39-50. 1947.

29. Emmet, A. D. and Grindley, H. S. A preliminary study of the effect of cold storage upon beef and poultry. Ind. Eng. Chem. 1: 413-436. 1909.

30. Ewell, A. W. The tenderizing of beef. Refrig. Eng. 39: 237-240. 1940.

31. Green, M. E. Some factors influencing the slicing quality and the palatability of canned beef. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1949.

32. Grindley, H. S. and Mojoinner, T. Experiments on losses in cooking meat. U. S. Dept. Agr. Expt. Sta. Bul. 141. 1904.

33. Hankins, O. G. Quality in meat and meat products. Ind. Eng. Chem. 37, no. 3: 220-223. 1945.

34. Hankins, O. G. and Ellis, N. R. Fat in relation to quantity and quality factors of meat animal carcasses. Proc. Am. Soc. Animal Prod. 32: 315-319. 1939.

35. Hankins, O. G. and Hiner, R. L. Freezing makes beef tenderer. Food Ind. 12, no 1: 49-51. 1940.

36. Harrison, D. L. Shrink, rate of heat transfer, and palatability of beef cooked at the same temperature in air, steam, water, and fat. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1943.

37. Harrison, D. L. Histological, physical, and organoleptic changes in three grades of beef during aging. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1947.

38. Hiner, R. L. and Hankins, O. G. Tenderness of beef as affected by aging with and without subsequent freezing. Refrig. Eng. 42: 172-174. 1941.

39. Hiner, R. L. and Hankins, O. G. Temperature of freezing affects tenderness of beef. Food Ind. 19: 1078-1081. 1947.

40. Hite, J. P., Klozin, S. E., Kummerow, F. A., Vail, G. A., and Avery, T. B. Fat rancidity in eviscerated poultry. III. The effect of variation of dietary fat, ethanolamine and choline, on the storage quality of mature turkeys. Poul. Sci. 28: 244-248. 1949.

41. Hite, J. P., Klozin, S. E., and Kummerow, F. A. Fat rancidity in eviscerated poultry. IV. The effects of variations in dietary fat, ethanolamine and choline, on the characteristics of the fat extracted from turkeys. Poul. Sci. 28: 249-253. 1949.

42. Howe, P. E. and Barbella, N. G. The flavor of meat and meat products. Food Res. 2: 197-202. 1937.

43. Lowe, B. and Stewart, G. F. Subjective and objective tests as food research tools with special reference to poultry meat. Food Tech. 1: 30-38. 1947.

44. Mackintosh, D. L., Hall, J. L., and Vail, G. E. Some observations pertaining to the tenderness of meat. Proc. Am. Soc. Animal Prod. 29: 285-289. 1936.

45. Maw, W. A. How breeding and feeding control poultry character and meat quality. U. S. Egg and Poul. Mag. 45: 608-612. 1939.

46. McCance, R. A. and Shipp, H. L. The chemistry of flesh foods and their cooking losses. Spec. Rpt. Series, No. 187, Medical Research Council, London. 1933.

47. McClurg, B. F. The quality and palatability of meat after storage in sub-freezing temperatures. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1940.

48. Mitchell, H. H., Zimmerman, R. L., and Hamilton, T. S. The determination of the amount of connective tissue in meat. J. Biol. Chem. 71: 379-387. 1927.

49. Morgan, A. F. and Nelson, P. M. A study of certain factors affecting the shrinkage and speed in roasting meat. J. Home Econ. 18: 371-378. 1926.

50. Noble, I. T., Halliday, E. G., and Klass, H. K. Studies on tenderness and juiciness of cooked meat. J. Home Econ. 26: 238-242. 1934.

51. Overman, A. and Li, J. C. R. Dependability of food judges as indicated by an analysis of scores of a food-tasting panel. Food Res. 13: 441-449. 1948.

52. Paul, P. C. Changes in palatability, microscopic appearance, and electrical resistance in beef during the onset and passing of rigor and during subsequent storage. Unpublished Ph. D. Thesis. Ames, Iowa, Iowa State College Library. 1943.

53. Paul, P. C. and Child, A. M. Effect of freezing and thawing beef muscle upon press fluid, losses, and tenderness. Food Res. 2: 339-347. 1937.

54. Paul, P. C. and McLean, B. B. Studies on veal. I. Effect of different internal temperatures on veal roasts from calves of three different weights. Food Res. 11: 107-115. 1946.

55. Ramsbottom, J. M., Strandine, E. J., and Koonz, C. H. Comparative tenderness of representative beef muscles. Food Res. 10: 497-509. 1945.

56. Ramsbottom, J. M., Strandine, E. J., and Koonz, C. H. Comparative tenderness and identification of muscles in wholesale beef cuts. Food Res. 13: 315-330. 1948.

57. Sartorius, M. J. and Child, A. M. Effect of coagulation on press fluid, shear force, muscle-cell diameter, and composition of beef muscle. Food Res. 3: 619-626. 1938.

58. Sartorius, M. J. and Child, A. M. Problems in meat research. I Four comparable cuts from one animal. II. Reliability of judges' scores. Food Res. 3: 627-635. 1938.

59. Sisson, S. and Grossman, J. D. The anatomy of the domestic animals. 3rd ed. Philadelphia, W. B. Saunders Co. 1938.

60. Steiner, G. Post-mortem changes in beef muscle at different temperatures as measured by its mechanical behavior. (Abstract) Chem. Abstracts 33: 2965. 1939.

61. Tanner, B., Clark, N. G., and Hankins, O. G. Mechanical determination of juiciness of meat. J. Agr. Res. 66: 403-412. 1943.

62. Thille, M., Williamson, L. J., and Morgan, A. F. The effect of fat on shrinkage and speed in roasting beef. J. Home Econ. 24: 720-733. 1932.

63. Wagoner, C. E., Vail, G. E., and Conrad, R. M. The effect of the degree of surface exposure on deterioration of frozen poultry. Poul. Sci. 26: 173-175. 1947.

64. Watts, B. M., Chunk, T. J., and Major, R. Effect of feeding and injecting hogs with tocopherols on the susceptibility of pork fat to rancidity. Oil and Soap 23: 254-257. 1946.

65. Watts, B. M. and Peng, D. H. Rancidity development in raw versus pre-cooked frozen pork sausage. J. Home Econ. 39: 88-92. 1947.

66. Wilson and Company. Yields from different grades and weights of steer carcass. Chicago, Agricultural Relations Division, Wilson and Company, Inc. 1943.

67. Winegarden, M. W. Physical and histological changes in three connective tissues of beef during heating. Unpublished M. S. Thesis. Ames, Iowa, Iowa State College Library. 1950.

ACKNOWLEDGMENTS

I wish to express my deep appreciation to Professor Belle Lowe for her interest, guidance, and assistance throughout the planning and execution of this project. Grateful acknowledgment is also extended to Mrs. Alma Plagge, Miss Madge Miller, Dr. Joseph Kastelic, and Mr. Edwin Kline who participated on the judging panel. For direction in the statistical analysis I should like to express my appreciation to Mr. Paul Homeyer and Dr. Bernard Ostle.