EFFECT OF TWO METHODS OF DRY HEAT COOKERY ON PALATABILITY AND COOKING LOSSES OF SEMIMEMBRANOSUS MUSCLE OF BEEF ROUND

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EFFECT OF TWO METHODS OF DRY HEAT COOKERY ON PALATABILITY AND COOKING LOSSES OF SEMIMEMBRANOSUS MUSCLE OF BEEF ROUND

By

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INTRODUCTION

Roast beef is a favorite menu item in many homes and institutions. Palatability characteristics and nutritive value are largely responsible for this popularity.

Research has contributed substantially to the knowledge of beef cookery and to the improvement of eating satisfaction in beef. Among the factors influencing the acceptability of the finished product are the cooking procedure, the degree of doneness, and the type and extent of connective tissue inherent in the selected cut.

Cooking methods used for meats are of two general types: moist heat and dry heat. In methods of cookery based on moist heat, the meat is surrounded by liquid as in stews, by steam as in cooking meat in steamers, or in roasting pans with tight-fitting lids. Dry heat cooking methods include those in which the meat is surrounded by air in the oven, under the broiler, over coals, or by a deep layer of hot fat.

The primary objective of this study was to secure comparative information concerning the effect of two methods of dry heat cookery--conventional oven-roasting and deep fat immersion--on cooking losses and palatability of semimembranosus muscle of U.S.D.A. Choice steer beef rounds.

It is an accepted fact that conventional oven-roasting usually necessitates the selection of tender, more expensive cuts of beef. Tender cuts of beef are those which contain relatively small amounts of elastin. They include roasts from the rib, loin, and sirloin sections of the beef carcass. Because the availability of these cuts from a single animal is limited, their purchase constitutes a large percentage of the total meat budget.

In comparison to the rib eye and tenderloin, the semimembranosus muscle, from the top round of beef, is less tender and, therefore, less expensive. Cooking by moist heat is usually recommended for this type of meat. During the cooking period, moisture in the presence of heat softens the larger percentage of connective tissue as well as the structural protein. However, many homes and institutions on limited budgets find it suitable to use selected cuts from top round of beef for conventional oven-roasting so that beef roasts may be included in their menus.

Optimum roasting temperatures involve the use of ovens for considerable lengths of time. For the homemaker, this factor often necessitates the preparation of certain foods in advance or it limits the menu to those items which do not require oven space, or to those which can be baked at the same temperature used for the meat. Lack of ovens at one's disposal creates identical problems in quantity food service operations. Furthermore, deep fat fryers in many quantity food service operations remain idle for much of the week. Therefore, if comparable palatability and yield could be maintained, development of an additional method of dry heat cookery, permitting utilization of less tender, lower-priced cuts for roasting as well as more efficient use of equipment, would be invaluable.

Directions for roasting meat usually indicate time required for cooking in terms of minutes per pound. At best these serve only as poor guides. Time required for roasting to a specified degree of doneness depends, in part, upon the rate at which heat is transferred from the particular cooking medium through the meat. A study to determine the thermal conductivity of beef muscle when cooked in fat and in air, and consideration of the rate of heat penetration as it relates to weight and shape of the roast may provide a more accurate basis for predicting cooking time for beef cooked in these media.

A second objective of this study, therefore, was to examine heat penetration data from the two cooking methods and investigate the potential for using such data as a valid basis for predicting cooking time for beef round.

It is hoped that findings from this study will contribute to the knowledge of beef cookery and be of value to those interested in effecting the preparation of palatable beef roasts with minimal cooking losses, and maximal economies in cooking time, in the use of equipment, and in fuel consumption.

REVIEW OF LITERATURE

According to Lowe (52) important factors which affect the tenderness of skeletal muscles of animals are (a) the age of the animal, (b) the kind and amount of connective tissue, and (c) the part of the carcass from which the cut is taken.

Hiner and Hankins (45) studied the tenderness of beef in relation to different muscles and age in the animal. From their work on fifty-two carcasses they classified the muscles within a given carcass into four major groups, ranging from the least tender to the most tender: neck and foreshank; round; rib, short loin, loin end, chuck at third rib and across humerus bones; and tenderloin.

Lowe (52) favors the classification of Hiner and Hankins and believes that it is a better one than the division into the two groups, less tender and tender. She further states that, in addition to varying degrees of tenderness, muscles also differ in shape, weight, fat content, collagen content, elastin content, and color. Differences in the size of fasciculi and the amount of connective tissue cause variations in the texture or grain of muscles.

In a study of the identification and comparative tenderness of fifty of the larger muscles of beef, Ramsbottom and Strandine (74) reported that the shear values of cooked beef of each muscle through the center of the round ranged from 8.1 to 12.0 pounds. Because of the variation in tenderness of muscles in beef round they recommend, wherever possible, the separation of tough and tender muscles for cooking.

Muscles of Beef Round

Tucker, Voegeli, and Wellington (90) divide beef round, cut according to the Chicago method, into two main areas, inside or top round and outside or bottom round. The semimembranosus and adductor muscles are the major muscles of the inside round. Other muscles in this area are the gracilis and pectineus. The semitendinosus, also known as the eye of the round, and biceps femoris are the muscles of the outside round. The remaining muscles--sartorius, vastus intermedius, vastus lateralis, vastus medialis, rectus femoris, and tensor fasciae latae--because of their lesser proportion are grouped together as the knuckle or tip.

Methods of Cooking Beef

Many research studies have been conducted concerning meat cookery. Meat experiments were carried out at the University of Illinois as early as 1898. Extensive investigations by the United States Department of Agriculture in cooperation with Agricultural Experiment Stations and colleges have resulted in improved cooking methods for beef.

Directions for the cooking of meat in experimental work have been specified by the Cooking Committee of the Cooperative Meat Investigations (17). These facilitate the comparison of results obtained in one laboratory with those in another. They are also designed to show differences in meat caused by various production and processing factors.

Methods of cookery used with meat are of two basic types: dry heat and moist heat. Tender cuts are usually cooked by dry heat. The meat is surrounded by dry air in the oven, under the broiler, over coals, or

by a deep layer of hot fat. Less tender cuts are generally cooked by moist heat and at temperatures at or near the boiling point.

Only research relating to conventional oven-roasting and cooking by deep fat immersion will be reviewed.

Conventional oven-roasting

For roasting meat uncovered pans are recommended. Although cooking time is somewhat longer, cooking losses and nutritive losses are reduced and the meat is more palatable.

According to Lowe (52) the oven temperature that produces the most palatable product with a minimum weight and nutrient loss in a reasonable cooking time with a small amount of fuel could be called the optimum cooking temperature. In their experiments, Lowe et al (53) cooked a large number of beef, veal, lamb, and pork roasts. They found the optimum oven temperature to be 150 to 160°C. At lower temperatures, the cooking time was longer and weight loss and fuel consumption were often greater than at 150°C. In addition, roasts cooked at lower temperatures, to well-done or very well-done, were tender but also dry. At higher temperatures, the cooking time was shorter but the amount of fuel needed as well as cooking losses were generally greater. Roasts cooked rapidly were juicier than those cooked very slowly for the same degree of doneness.

Cooking in deep fat

Reports on the use of deep fat as a cooking medium for experimental work on beef roasts have been few. Harrison (40) compared the palatability of beef roasts cooked at the same temperature in four different media:

air, steam, water, and fat. Harrison, Lowe, McClurg, and Shearer (41) used fat held at temperatures of 96 to 98°C to cook beef muscles to an internal temperature of 70°C. In their study, Ramsbottom, Strandine, and Koonz (76) cooked beef muscles to 76.7°C using a fat temperature of 121.1°C. Recently, Visser et al (92) compared tender and less tender beef muscles, from paired U. S. Good long hind quarters, cooked to internal temperatures of 55, 70, and 85°C, by oven roasting at 149°C, cooking in deep fat at 110°C, and cooking in deep fat at 100°C.

Smoke point. Lowe (52) states that the chemical and physical characteristics of a fat are important and that it is preferable to use fats with high smoking temperatures for frying. Through experiments made on doughnuts, Lowe, Pradhan, and Kastelic (54) presented information on the smoke points of continuously used cooking fats. They found that the initial free fatty acid content was lowest in oils, slightly higher in hydrogenated shortenings, and highest in lards. During cooking, the free fatty acid content of all fats increased and the smoke point was lowered. However, this relationship tended to be greater in fats with an initial low fatty acid content. Lowe (52) also pointed out that the fatty acid content of animal fats varied with the location in the body and with the feed the animal had received.

In a study to determine whether the smoke point is affected by the determination method, Swartz (84) used the official cup of the American Oil Chemists' Society, a small iron skillet, an enameled kettle, and an iron Dutch oven. Smoke points for all-hydrogenated fats varied from 171 to 222°C. Those determined by the official method were higher in every case and the use of larger utensils resulted in a lower smoke point.

Vail and Hilton (91) reported smoking temperatures ranging from 245 to 190°C for 17 vegetable fats and oils. They found that when samples were heated for 2-, 6-, 12-, and 20-hour periods the percentage of free fatty acids increased with each increment of time. Although the rate of increase was not consistent, as the percentage of free fatty acids increased the smoking temperature of the fat decreased.

Factors Affecting Rate of Heat Penetration

The time required for cooking meat is usually estimated in terms of minutes per pound. At best, this can only serve as a general guide. Important factors which cause variations in cooking time required for meat are: composition, size, shape, extent of aging, initial temperature, method of cooking, cooking temperature, and degree of doneness.

Composition of the meat

The constituents of a cut of meat have different rates of heat conductivity. Towson (89) cooked paired prime ribs of beef at 125 and 200°C to an internal temperature of 63°C. During cooking, temperatures were recorded at the center, which was 2 inches from either cut surface of the longissimus dorsi muscle, and at 0.5 inch below the surface of the fat over the top of the roast. She found that when the surface fat was deeper than 0.5 inch, so that the thermometer bulb was imbedded in the fat, heat penetrated the 0.5 inch layer of fat more slowly than the 2 inches of lean.

Lowe (52) studied the rate of heat penetration in muscular and fatty tissue. Pint jars were filled with lean beef, lean pork, fat pork, and suet. A thermometer was inserted through the rubber cork in the lid of each jar and positioned in the center of the jar. Jars were placed in a processing container and heated in boiling water and steam for 3 hours. Results showed that heat penetrated the lean beef most rapidly, followed by lean pork, fat pork, and suet.

Thille, Williamson, and Morgan (88) experimented with three-rib beef roasts cooked in ovens preheated to 225°C and then maintained at 210°C until an internal temperature of 65°C was reached. They found that fat played a significant role in the speed at which heat penetrated the meat and concluded that, because of the change in heat conductivity as fat passes from a solid to a liquid, exterior fat speeds up the heat penetration rate, but interior fat may retard it.

According to Lowe (52), meat composition affects the duration of temperature rise more than the extent. Meat containing a great deal of fat and meat that has a very thick layer of surface fat requires a long time for the inner temperature to reach its maximum point. Such a roast may take 1 to 1.5 hours to reach its maximum inner temperature after the cooking process is stopped, while a lean roast of the same weight and shape, cooked under the same conditions, may take only 12 to 30 minutes.

<u>Weight and surface area</u>

As the size of a piece of meat increases, its weight increases in greater ratio than its dimensions. Because heat must travel from the surface inward, the greater the surface area the shorter is the cooking time. Thus, if other conditions are standardized, large roasts will require fewer minutes per pound than smaller similar cuts (52).

In their study of 5-, 10-, and 15-pound top round beef roasts, Marshall, Wood, and Patton (57) found that a longer total cooking time was required as size and degree of doneness increased. However, fewer minutes per pound were required for cooking the larger roasts. The difference in average total cooking time increased with the degree of doneness until an internal temperature of 75°C was reached, after which it appeared to stabilize or decrease. This difference was greater between the 5- and 10-pound roasts than between the 10- and 15-pound roasts. Approximately 1 to 1.5 hours longer were required to cook the 10-pound roasts than the 5-pound ones. Average total cooking time of the 15-pound roasts was approximately 0.5 to 1.5 hours more than for the 10-pound roasts.

Lowe (52) states that in larger pieces of meat, the size of the piece may not be too important a factor in affecting the temperature rise of the interior after cooking has been stopped. However, a piece of meat may be so small or thin that the inner temperature does not rise after the cooking process has stopped, because of rapid cooling from the surface.

<u>Aging</u>

Paul and Bratzler (65) studied the effect of storage by cooking steaks from semimembranosus and adductor muscles in deep fat. When the muscles were considered separately, increased storage tended to shorten cooking time, but to increase cooking losses for semimembranosus steaks. In the adductor, cooking time also decreased slightly with increased storage, while cooking losses did not differ significantly.

Hanson, Stewart, and Lowe (39) observed that cooking time decreased significantly as the time between killing and cooking of New York dressed broilers increased. Heat penetrated the muscles more rapidly as postmortem changes progressed.

Initial temperature of the meat

Cooking time is influenced by the temperature of the meat at the beginning of the cooking period. Meat having a temperature of 0 to 5°C requires a longer time than meat having an initial temperature of 20°C. Meat frozen when cooking is started requires a longer cooking time. Part of the heat is used to melt the ice before the temperature can be elevated above the freezing temperature of the meat (52).

Cooking method, temperature, time

Meat may be cooked in four mediums—water, steam, fat, or air. If the temperature of these cooking media is constant, cooking time depends largely upon the rate at which heat is conducted in the particular cooking medium being used. Since the specific heat of air is 0.24 and of oil is 0.41 to 0.43, meat reaches a definite interior temperature faster in oil than in air of the same temperature (52).

Cover (18) investigated the rate of heat penetration in beef cooked in water and in an oven of the same temperature. She reported cooking time was short in "moist heat" as compared with "dry heat" of the oven. Harrison (40) found that cooking time for beef was shortest in water followed by fat, steam, and air. She also noted that the rate of temperature rise for roasts cooked in the oil medium was approximately the same throughout cooking. However, after oven roasts reached a temperature of 50 to 55°C, the rise in temperature at the center of the roasts was slower than in the first part of the cooking period.

Marshall, Wood, and Patton (58) also observed that the rate of increase in internal temperature lessened as roasts approached the rare stage. They suggest that since this is an endothermic process, less heat is available to raise the temperature of the roast. Marshall and coworkers (58) found the rate of increase in internal temperature was least in a 93°C oven. Meat cooked to well-done at this temperature had a final internal temperature only 5°C less than that of the oven.

If other conditions are constant, cooking meat rare requires less time than cooking it medium or well-done. Marshall, Wood, and Patton (58) also reported a wide variability in cooking time which was particularly striking for roasts cooked to 70 and 80°C in a 93°C oven. Less variation was evident for roasts cooked at the higher temperatures, 107 and 121°C. Cooking times were most uniform for roasts cooked to 60°C.

From their experiment, Visser et al (92) reported time-temperature curves for roasts cooked in fat were steeper and shorter than those for comparable oven roasts. They estimated that at a given temperature the heat conductivity of liquid fat is about 6 times that of air. The fat transferred heat to the meat more rapidly than did the air in the oven, although the temperature of the fat was lower than that of the oven.

According to Lowe (52), the lower the inner temperature at which the cooking is stopped, the greater is the tendency for the rise of inner temperature. This is due to the variation between the inner and surface heat. At internal temperatures of 75°C or above there is usually little or no rise in temperature after cooking is stopped.

Visser et al (92) reported no internal temperature rise of oven roasts cooked to 55, 70, or 85°C. However, when meat was cooked in deep fat at 110°C, the internal temperature of roasts cooked to 55°C rose 10 to 13°C, and the temperature of roasts cooked to 70°C rose 5 to 6°C. The rise in temperature of roasts cooked to 85°C was negligible. Internal temperature rise for roasts cooked in deep fat at 100°C to 45 and 65°C was approximately 10 and 5°C, respectively, whereas the rise for roasts cooked to 85°C was negligible. Thus, for roasts cooked in deep fat, there were no samples representative of rare and medium-done meat.

Factors Affecting Cooking Losses

The total loss that occurs during the cooking of meat includes both volatile and dripping losses. The greater portion of volatile loss is from the evaporation of water, while the drippings include fat, water, salts, and nitrogenous and non-nitrogenous extractives. Depending on the temperature of the cooking medium and the stage to which the meat is cooked, total losses occurring during the cooking of meat may vary from approximately 5 to more than 50 per cent (52). In general, factors which may influence cooking weight losses are the same as those which affect the rate of heat penetration.

Composition of the meat

In early research on the cooking losses of meat, Grindley and Mojonnier (35) observed that both water and fat accounted for weight loss in roasted meats. Lowe (52) pointed out that the ratio of evaporation losses to dripping losses was higher for lean meat and lower for fat meat. Black, Warner, and Wilson (6) found meat from supplement-fed steers showed more dripping loss and less evaporation loss during cooking than did meat from thinner, grass-fed cattle. Thille, Williamson, and Morgan (88) roasted standing ribs of beef at 210°C to an internal temperature of 65°C and found the average total weight loss was 29 per cent for lean roasts and 33 per cent for fat-covered roasts. These workers attributed the difference in total weight loss to the rendering out of surface fat.

Grade

From studies of beef roasts ranging from Choice to Canner grade, Alexander (2) reported well-fattened beef ribs of high grade had greater dripping losses and lower volatile losses than did lean ribs of low grades. Dripping losses from roasts cooked at an oven temperature of 125°C to 58°C internal temperature varied from 3.7 per cent for Choice grade to 0.4 per cent for the Canner grade; evaporation losses ranged from 6.5 per cent for Choice to 10.9 per cent for the Canner grade. The results of Black et al (6) were in agreement with these findings. In their work, Alexander and Clark (3) noted that among roasts classified according to grade, those in the highest grade usually showed smaller evaporation losses and larger dripping losses, irrespective of style of cutting or method of cooking.

Masuda (59) reported no significant difference in volatile losses attributable to grade; differences in dripping losses due to grade were significant only at 90°C internal temperature. The average dripping losses at 90°C for Good and for Choice grades were significantly higher than for Commercial grade. There was no significant difference between average total cooking losses attributable to grade at any of the internal temperatures. In working with longissimus dorsi muscle of U. S. Utility, Commercial, and Good grades of beef cooked to 80°C at 149°C, Day (29) found no significant difference attributable to grade in average total cooking losses, volatile losses, or drip losses.

Surface area

Extensive investigations (42,53) showed that compact pieces of meat with small surface areas have less cooking weight losses than cuts which have irregular shapes and greater surface areas. In their work with 5-, 10-, and 15-pound cuts of Choice top rounds of beef, Marshall, Wood, and Patton (57) found that the size of the roast affected total preparation losses. Cooking losses for 10- and 15-pound roasts were significantly less than for the 5-pound roasts at all degrees of doneness except rare.

Aging

Moran and Smith (61) observed that longer ripening periods after slaughter reduced cooking losses. Harrison (40) noted roasts with a longer ripening period had less weight loss when cooked in air than when cooked in steam, fat, or water. In cooking steaks in fat, Paul and Bratzler (65) found cooking time decreased with increased storage, and cooking losses tended to increase with cooking time.

Cooking method, temperature, time

Cline and co-workers (16) reported that both cooking losses and cooking time were affected by the initial temperature of roasts. Roasts with low internal temperatures at the beginning of the cooking period showed greater cooking losses than did roasts with higher initial temperatures.

The effect of four methods of defrosting meat and the manner and temperature of cooking upon weight loss and palatability of roasts were compared by Lowe and associates (53). Frozen cuts of meat required a

longer cooking time than comparable cuts which were thawed. However, data for 41 groups of roasts indicated cooking losses for frozen cuts were not always greater than those of the defrosted meat. In 31 of these groups weight loss was greater for roasts which were frozen when cooking started. The other 10 groups of roasts gave opposite results.

Cline et al (16) reported results of several methods of roasting beef. They seared prime ribs and cooked them at different oven temperatures. They concluded that searing increased cooking losses and low oven temperatures were correlated with low cooking losses. From their studies, Child and Satorius (14) found cooking losses in beef were greater when meat was roasted at constant temperatures of 200 and 175°C or seared at 260°C for 20 minutes and finished at 150°C than when roasts were cooked at a constant temperature of 150°C.

Cover (23) observed cooking losses for paired three-rib roasts cooked medium-rare averaged 7.1 per cent when a 125°C oven was used and 20.2 per cent when a 225°C oven was used. Lowe (52) found 12 pairs of two-rib beef roasts cooked at 150°C showed 7.7 per cent cooking loss at 55°C internal temperature and 16.6 per cent cooking loss at 75°C internal temperature. Other workers (2, 53) have reported similar findings.

The effect of five different internal temperatures on the cooking weight losses of roasts prepared from tender cuts of beef was studied by Masuda (59). As was expected, the total cooking losses increased with each rise in the internal temperature of the meat. The cooking losses of the strip loin at each of the internal temperatures were significantly lower than those of any of the other cuts with the exception of the posterior round at 50°C internal temperature. Generally, at 50, 60, and

70°C internal temperatures, the average total cooking loss of the rolled rib roasts was higher than that of the top round cuts; but at 80 and 90°C, round cuts showed higher cooking losses than rolled rib cuts.

In their experiment with top round beef roasts cooked to internal temperatures of 60, 65, 70, and 80°C in a 149°C oven, Marshall and co-workers (57) found cooking losses increased with degree of doneness up to the medium-well done stage and were greater in 10- and 15-pound roasts than in 5-pound roasts at all degrees of doneness except rare.

In a recent study, Marshall, Wood, and Patton (58) compared preparation losses, cooking time, and yield of 10-pound pieces of Choice grade top beef round roasted to three internal temperatures (60, 70, and 80°C) at three oven temperatures (93, 107, and 121°C). They concluded that total losses were greatest in the 93°C oven, and at all oven temperatures there were greater losses at the higher internal temperatures. Evaporation losses varied with oven temperature and increased with internal temperature in low temperature roasting of beef. Drip losses increased as both oven temperature and internal temperature of the roast increased.

Cover (20) studied the effect of metal skewers on cooking time and cooking losses. Paired round, armbone chuck, and standing rib roasts were cooked to the well-done stage with and without skewers at an oven temperature of 125°C. Total loss of weight was reduced in skewered roasts by about 35 per cent while cooking time was shortened by approximately 30 to 45 per cent.

The total losses of meats roasted in covered and uncovered pans were compared by Grindley and Mojonnier (35). Analysis of the data showed that weight losses were greater for covered than for uncovered roasts.

Harrison (40) noted roasts cooked in deep fat had the greatest loss in weight and volume, while those cooked in air had the least loss. Total losses obtained from comparable cuts cooked in steam and in water were similar and gave intermediate values.

In their recent study, Visser et al (92) found that as the internal temperature of the meat increased, average cooking time increased significantly, and was accompanied by a significant increase in cooking losses for all beef round roasts except those from the adductor and posterior semimembranosus muscles cooked in 100°C fat. The effect of internal temperature on cooking time and losses was most pronounced in oven roasts and least pronounced in those cooked in deep fat at 110°C. When the end temperature was 55 or 70°C, losses were greater for roasts cooked in deep fat than for oven roasts. However, when the meat was cooked to 85°C, losses were similar for all methods.

Factors Affecting Palatability Characteristics of Meat Cooked by Dry Heat

Extensive research has shown that the eating quality of meat is dependent upon numerous and varied factors. Carcass grade, sex, breed, muscle differences, aging, freezing, and method and extent of cooking are included among factors influencing the acceptability of the finished product. The palatability characteristics considered in judging cooked meats are: aroma, flavor, appearance, texture, tenderness, and juiciness.

Aroma and flavor

Although flavor and odor components of meat are not well defined, these qualities, in a properly cooked piece of meat, are largely responsible for appetite appeal.

The weak, blood-like flavor of raw meat, Crocker (26) points out, is primarily in the juice, rather than in the fiber. 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. Kramlich and Pearson (49) found the flavor constituents of raw beef and beef juice fractions largely water soluble.

Cooking develops the "meaty" flavor which Crocker (26) states is presumably brought about by certain chemical changes in the fiber, not in the juices. The variety of chemical compounds formed during cooking include ammonia, amines, an indole-like odor, hydrogen sulfide, and acids such as acetic and propionic. Complex combinations of small amounts of these compounds result in the fragrant and distinctive "meaty" flavor, which is largely an odor. These pleasant, slightly burnt, moderately acid, sulfury odors and flavors intensify to about 3 hours of cooking and then gradually decrease.

Howe and Barbella (46) attribute flavors of cooked meat to the 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 resulting from these products and the proteins.

Kramlich and Pearson (49) found flavor constituents of longissimus dorsi muscle of beef rib were largely water soluble in both raw and cooked fractions. Cooking before extraction of the sample increased flavor threshold. This suggests that full flavor development may be due to heating of juice and fibers together.

Grade. Several investigators (29,36,59) have observed that carcass grade influenced the palatability of cooked meat. Day (29) reported significant differences in grade for aroma and flavor when longissimus dorsi muscles of U.S. Good, Commercial, and Utility grades were compared after roasting. Masuda (59) worked with top rounds, sirloin butts, strip loins, and rolled ribs cut from three grades of beef carcasses, Choice, Good, and Commercial. Statistical analysis showed average aroma and flavor scores of Commercial grade roasts to be significantly higher than those from Good and Choice grade roasts. In comparing 40 Choice, 76 Good, and 24 Commercial grade rib roasts, Lowe et al (53) obtained highest scores for aroma and flavor from the Choice grade. Griswold (36) found Prime grade beef gave higher palatability scores than Commercial grade.

Degree of finish and fat content. From their study on the relation of degree of finish in cattle to meat flavors, Branaman and co-workers (10) observed that the scores on intensity and desirability of flavor of lean meat showed progressive improvement in the meat with increased fat.

Simon, Carroll, and Clegg (80) studied the effect of degree of finish on differences in quality factors of beef. Results indicated that flavor, juiciness, and tenderness differences became more apparent with increasingly wider differences in degree of finish and carcass grade. Flavor appeared to be associated with intramuscular fat. However, the relationship of per cent carcass fat with quality scores did not show striking correlation. Dunnigan (32) worked with Choice and Utility grades of sirloin butts cut in two styles, bone-in and bone-out, and reported fat roasts scored significantly higher than lean roasts in aroma, flavor, and tenderness.

Kramlich and Pearson (49), in working with beef and beef juice fractions, found that neither fat content nor fat-free dry matter were responsible for differences in flavor when flavor threshold and gross chemical analysis were compared.

Deterioration in palatability of beef, pork, and lamb during freezer storage at temperatures between -7.78 and -17.8°C, was found by Hiner, Gaddis, and Hankins (43) to be due primarily to the oxidation of fat. They also noticed that the desirability of the flavor of the fat was the best subjective index among the palatability factors studied.

Aging. According to Lowe (52), aging includes the entire storage period from the time of slaughter until the time the meat is cooked. The effects of aging have been shown to have a marked influence on palatability. From observing histological, physical, and organoleptic changes in beef during aging, Harrison et al (41) found little variation in aroma and flavor scores for roasts aged from 1 to 20 days, although the highest average scores were received by roasts aged 10 days. When roasts were stored longer than 20 days, aroma and flavor scores were definitely lower than for roasts stored less than 20 days. Lowe (52) observed that aging meat 20 to 40 days imparted optimum flavor. Meat aged longer than 40 days usually had too "high" a flavor for most of the judges in her laboratory.

Griswold and Wharton (37) studied the effect of storage conditions on the palatability of beef. The aroma and flavor of meat stored 37 days at 1°C were slightly stronger than for meat stored 9 days at the same temperature. Meat which had been stored 48 hours at 15°C under ultra-violet lights was more desirable in appearance and odor than meat held under similar conditions without ultra-violet lights. These lights decreased the growth of bacteria on the meat surface.

From their investigation on the changes in beef induced by storage, Paul, Lowe, and McClurg (68) reported that the greatest increase in palatability of small cuts was obtained with a 9-day storage period at 1.7°C. Further storage resulted in decreased desirability of aroma and flavor and development of "gaminess" in the lean and rancidity of the fat.

Freezing. Hiner, Gaddis, and Hankins (43) stored cellophane wrapped, lard-coated, vacuum packed, and exposed beef, pork, and lamb chops at -7.78, -9.44, -17.8, and -81.1°C. The exposed meat had a good covering of fat, which partially prevented it from drying out. Cellophane and lard-coating were equally satisfactory in protecting frozen cuts from moisture loss. The most dessication occurred in the exposed cuts. Development of undesirable flavor was not attributable to fat oxidation alone but appeared to be related to moisture loss as well. The original quality of all the meat declined rapidly in all types of protection studied except the vacuum pack. Temperatures of -17.8°C and below gave the best protection to the meat.

In a study concerning the effect of four different packaging materials on frozen meats, Simpson and Chang (81) found that aluminum foil or glassine-laminated paper was more effective than polyethylene-coated paper or butcher wrap in retarding rancidity development. They used storage temperatures of -17.8, -28.8, -34.4, and -40°C and observed that temperatures of -28.8°C or lower gave the best protection to the meat.

Method and extent of cooking. In comparing the effect of different cooking methods, Griswold (36) found beef round roasted at 121°C scored high in acceptability and flavor. Stech and West (83) reported similar findings. From their experiments with 10 methods of roasting prime ribs of beef, Cline et al (16) observed a definite correlation between cooking losses and flavor of the lean. All roasts which ranked low in cooking losses rated high in palatability. They also noted tender cuts cooked in the oven at 125°C with the addition of water had lower flavor and aroma scores than comparable cuts cooked in the oven by dry heat at 125°C.

The findings of Clark and Van Duyne (15) indicated that oven cooking resulted in more palatable top rounds than did cooking similar roasts in the pressure saucepan. Judges preferred the flavor of the lean and fat of the meat roasted in the oven and considered the meat cooked in the pressure sauce pan too dry.

Appearance and texture

Because eye appeal influences food selection, texture, appearance, and color are important characteristics of meat.

From a study of factors influencing the tenderness and texture of beef, Brady (8) stated that texture is dependent on the size of the fiber bundles in the muscle, the larger bundles being associated with finer texture.

Grade. Satorius and Child (78) reported that judges' scores showed no significant difference between medium and good grades in the external appearance of longissimus dorsi and adductor muscles roasted to 58°C in a 150°C oven. However, they observed a significant difference between grades in the external appearance of the raw muscles.

In her work with the longissimus dorsi of beef from U.S. Good, Commercial, and Utility grades, Day (29) reported that, for appearance and texture, the analysis of taste panel scores indicated little difference between grades. Masuda (59) found the average appearance scores from cooked samples of Commercial and Good grade roasts were significantly higher than scores for samples from comparable cuts of Choice grade roasts. No significant difference in texture scores attributable to grade was observed.

Color. Although some red corpuscles with their hemoglobin remain in the capillaries when the blood is drained from the animal at the time of slaughter, myoglobin is the chief pigment producing the pink to red color in muscle. Bernofsky, Fox, and Schweigert (5), in studying the effect of cooking on myoglobin, reported that pigments extracted from cooked fresh beef consist mainly of oxymyoglobin. The amount of pigment remaining undenatured in a piece of cooked meat depends upon its temperature and how long it has been held at that temperature.

Tappel (87) found reflectance spectrophotometry useful in studying hematin pigment changes in the cooking of beef and in characterizing the hematin pigments of cooked beef. Choice beef tenderloin steaks were broiled to medium-rare and well-done. The entire visible spectra from 400 to 600mu was recorded. He observed that hematin pigments have a relatively sharp and characteristic reflectance spectra minima. Brown pigments of cooked beef are characterized as mixed denatured globin nicotinamide hemichromes.

Method and extent of cooking. Bramblett et al (9) studied five muscles from paired beef rounds wherein one muscle from each pair was cooked at 63°C for 30 hours and the other at 68°C for 18 hours. The meat cooked at 63°C yielded higher appearance and texture scores than the meat cooked at 68°C.

Marshall and co-workers (58) roasted top round of beef at three oven temperatures to three internal temperatures. They found that appearance tended to be scored lower as degree of doneness increased, possibly due to the relatively drier appearance and the ragged edges. Roasts cooked to well-done developed a hard crust which was difficult to cut, causing the meat to tear during slicing.

From their study, Visser et al (92) reported that the external appearance of all roasts cooked in the oven or in deep fat was similar. However, the surface of meat cooked in hot fat was the gray-brown color of cooked meat, but not the rich brown characteristic of the oven roasts. The center of deep fat roasts cooked to 45°C was a bright pink which gradually faded to a gray-brown around the edge. The center of roasts cooked to 65°C was a light pink that faded to gray-brown about half way through the roast, whereas the interior of roasts cooked to 85°C was a uniform gray-brown. The inside appearance of oven roasts was typical of rare, medium-, and well-done meat.

Tenderness

Since nearly everyone who eats meat notes its tenderness, this quality in meat is universally desired. Factors which affect the tenderness of meat have been the subject of many investigations.

Composition of the meat. Black, Warner, and Wilson (6) studied the effect of grade and feeding of grain supplement to steers on the quality of beef. From judges' scores and mechanical shear tests they found meat from steers fed the grain supplement was more tender than meat from grass-fed steers. Simon, Carroll, and Clegg (80) observed that differences in tenderness became more apparent with increasingly wider differences in degree of finish and carcass grade.

Cover, King, and Butler (25) measured the per cent separable fat and the per cent ether extract in studying the effect of fatness. They reported a wide scattering of tenderness rating for meat from different carcasses. Agreement between fatness and tenderness was low enough to indicate that a consumer who buys fat or well-marbled loin steaks may be disappointed in tenderness. Using sixty-nine grain-fed cattle, Hankins and Ellis (38) found no significant correlation between fat content determined by ether extract, and tenderness of cooked longissimus dorsi muscle. They concluded that variations in tenderness are caused mainly by factors other than fat content.

Ramsbottom and Strandine (74) investigated the comparative tenderness of samples from eight muscles of U.S. Good beef and observed no relationship between the amount of fat within the muscle and shear force results for raw or cooked samples. They emphasized that the amounts of collagenous and elastic connective tissue in the muscle influenced the tenderness of the cooked muscles.

Brady (8) stated that texture is an indication of tenderness and, the "finer" the texture, the tenderer the meat.

Age, sex, and grade. To determine the effect of animal age on the tenderness of the meat, Hiner and Hankins (44) used animals varying in age from 25 months to 5.5 years. Tenderness decreased as the age of the animals increased. From their experiments, Satorius and Child (78) concluded that meat from steers was more tender than that from cows.

Lowe et al (53) cooked 40 Choice, 76 Good, and 24 Commercial prime ribs at oven temperatures of 120, 150, and 175°C to internal temperatures of 58 and 75°C. According to palatability scores, tenderness was influenced by carcass grade. Commercial grade roasts received lower tenderness scores than roasts from Choice and Good grade carcasses. Choice grade was scored slightly higher than Good. Masuda (59) also reported that average tenderness scores for samples from Choice grade roasts were significantly higher than those from Commercial and Good grade roasts. Shear force readings and tenderness scores indicated a probable high negative correlation.

In their study, Cover, King, and Butler (25) obtained a wide scattering of tenderness ratings for different animals within a grade. Tenderness ratings were as high for meat in some carcasses of lower grade as for meat from other carcasses in higher grades. This would suggest that, for their sample, carcass grade was not satisfactory as an exact indicator of tenderness in meat.

Animal and muscle variations. Noble, Halliday, and Klaas (62) found very small differences between tenderness averages for corresponding left and right wholesale rib cuts when the cuts were cooked in the same manner. They also noted that rib cuts were one and one-half times more tender than first round cuts from the same animal.

Ramsbottom and Strandine (74) observed individual muscles within a carcass varied markedly in tenderness. They reported the longissimus dorsi and the psoas major averaged higher in tenderness than any other muscles with the exception of the internal oblique. However, Griswold (36) found no significant difference in palatability or shear values between the semimembranosus and biceps femoris muscles of beef.

Aging. Ramsbottom and Strandine (75) reported that beef was more tender two hours after slaughter than at any time after two to six days. Between the 9th to 12th day after slaughter, beef was even more tender than it had been two hours following slaughter.

Paul and co-workers (66) used the semitendinosus and biceps femoris muscles in comparing steaks fried in deep fat with roasts cooked in the oven after 0, 5, 12, 24, 48 to 53, and 144 to 149 hours of cold storage following slaughter. They found tenderness changed with storage. Roasts were least tender immediately after slaughter and as storage time increased, tenderness increased. Steaks were tender immediately after slaughter, became less tender with storage up to 24 hours, and returned to their original tenderness at the end of the storage period. These results are in agreement with the earlier and similar findings of Paul and Child (67).

Freezing. In her study on the tenderness of precooked and fresh frozen roasts of beef, Dahlinger (27) reported that Warner-Bratzler shear measurements were significantly higher for precooked roasts. Taste panel scores for tenderness, however, indicated a preference for the fresh frozen beef roasts.

Paul and Child (67) observed no significant difference in the tenderness of meat which was not frozen and meat which was frozen at -18°C. According to Ramsbottom (73), freezer storage at -23°C or lower for seven years did not significantly change the tenderness of beef steaks.

Method and extent of cooking. From their study, Ramsbottom, Strandine, and Koonz (76) found most beef muscles were made less tender by cooking, some did not change significantly, and other muscles became more tender. They concluded that since connective and fatty tissues were made more tender by cooking, decreased tenderness of certain cooked muscles might be associated with factors such as coagulation and denaturation of muscle protein together with varying degrees of shrinkage and hardening of the muscle fibers.

Cover, Bannister, and Kehlinbrink (24) showed that tenderness has more than one component and that longissimus dorsi and biceps femoris muscles differed markedly in tenderness response to certain cooking conditions.

Child and Satorius (14) roasted semitendinosus muscles from beef round at oven temperatures of 125, 150, 175, and 200°C to an internal temperature of 58°C. They reported no difference in the shear force tests for these roasts. In studying the relationship between oven temperature and tenderness, Cover (23) used constant oven temperatures of 125 and 225°C to roast beef to an internal temperature of 80°C. Round-bone chuck, rib, and rump roasts were more tender when cooked at 125°C than when cooked at 225°C. However, no difference in tenderness was shown in medium-rare rib and chuck roasts cooked at 125 and 225°C. Relatively small differences in total cooking time were observed. In another study, Cover (19) noted the effect of oven temperatures of 80 and 125°C on beef tenderness. Results of this experiment showed that roasts were always tender when cooked at 80°C. However, they were dry, mealy, and flavorless.

Several investigators have studied the effect of roasting meat at 121°C. Stech and West (83) reported products were tender, moist, and had good flavor. Griswold (36) stated that roasting at 121°C was a superior method for cooking beef round except for the dry appearance of the surface.

Noble, Halliday, and Klaas (62) determined the tenderness of beef cooked to 61 and 75°C internal temperature in a 149°C oven. From the penetrometer readings, they concluded that toughening occurred during heating from 61 to 75°C.

From her study Harrison (40) reported that the taste panel found meat cooked in fat more tender than oven roasts. However, shear score values were lower for roasts cooked in air. Visser et al (92) found little difference in subjective tenderness scores for samples roasted in a 149°C oven and those cooked in fat at 110°C whereas, scores for samples cooked in 100°C fat were slightly lower. Generally, shear values were a little lower for oven roasts than for those cooked in fat. These workers observed that, irrespective of degree of doneness, shear values and tenderness scores did not vary significantly for a given muscle.

Juiciness

Juiciness enhances palatability and quality and, therefore, influences the acceptability of cooked meat. From her studies in standardizing methods of roasting beef, Latzke (50) stated that juiciness can be measured to some extent by the amount of cooking losses in meat. Other workers (9,69) have also observed an inverse relationship between juiciness and cooking weight losses.

Composition of meat. Barbella et al (4) used 728 rib roasts to study the flavor and juiciness of beef in relation to fatness and other factors. They noted that juiciness of roasts increased quite rapidly with increase of fatness up to 22.5 per cent and more slowly from that point to 42.5 per cent. There appeared to be no apparent relationship between fatness and juiciness beyond the 42.5 per cent level. Thille, Williamson, and Morgan (88) reported that fat-covered beef roasts were less dry than lean roasts.

From their study, Child and Esteros (13) observed that standing rib roasts scored higher than comparable boned roasts when tested with a pressometer or scored for juiciness by a panel.

Grade and muscle. Day (29) concluded that there was little difference in average subjective scores for juiciness of U.S. Utility, Commercial, and Good grade cuts cooked to the same degree of doneness. She obtained a significant positive correlation between press fluid tests and juiciness scores at the 5 per cent probability level.

Masuda (59) found no significant difference in juiciness attributable to grade. However, average juiciness scores of strip loin were significantly higher than those of any other cut whereas, scores for center cuts of top round averaged lower in juiciness and tenderness than did any of the other cuts.

Aging and freezing. Harrison (40) observed little variation in juiciness scores of roasts aged from 1 to 20 days at 0°C. From their investigation, Paul, Lowe, and McClurg (68) reported a gradual increase in juiciness scores during 18 days of aging. Press fluid decreased and then increased sharply during storage. They attributed this to changes in the water-binding powers of the proteins and the permeability of the cell membranes. Paul (64), in studying the effect of storage on palatability characteristics and physical changes in beef, also noted a reduction in press fluid during the first few days, followed by a sharp increase between the 9th and 18th day of storage.

From a study concerning the effect of freezing, Paul and Child (67) reported that unfrozen beef roasted at 175°C to 58°C was significantly higher in press fluid than frozen beef cooked at 175°C to the same degree of doneness.

Method and extent of cooking. Noble, Halliday, and Klaas (62) found beef rib roasts cooked to 61°C juicier than comparable roasts cooked to 75°C. According to their findings, beef rounds yielded more juice than rib roasts at both degrees of doneness. Satorius and Child (79) reported a decrease in press fluid in the semitendinosus of beef by increasing the internal temperature from 67 to 75°C. However, they obtained no such decrease by increasing internal temperature from 58 to 67°C.

Cline et al (16) cooked beef at oven temperatures of 110, 163, 191, 218, and 260°C, to an internal temperature of 57°C. From their investigations, it appeared that high temperature decreased the juiciness of roasts. Child and Satorius (14) found that oven temperatures of 125, 150, 175, and 200°C did not affect the press fluid of beef muscles cooked at

58°C. In their study, Bramblett and co-workers (9) noted that meat cooked at 63°C for 30 hours gave greater press fluid yields and higher scores for juiciness than meat cooked at 68°C for 18 hours.

According to Harrison (40), panel members found no significant difference in juiciness of meats cooked in four media. There was no significant difference in the amount of press fluid at the center of roasts due to cooking mediums; but there was a highly significant difference in the amount of press fluid from samples one-half inch below the surface of roasts which was attributable to different cooking mediums. Meats cooked in air had the most press fluid. Cuts cooked in fat were next, followed by water and steam.

In their study, Visser et al (92) noted beef cooked in a 149°C oven or in deep fat at 100°C was juicier than beef cooked in fat at 110°C. Juiciness scores and press fluid yields for oven roasts and those cooked in deep fat at 100°C usually decreased significantly as the internal temperature of the roasts increased. There were fewer differences in juiciness attributable to internal temperature for roasts cooked in deep fat at 110°C.

Methods of Evaluating Palatability

Food acceptability is primarily dependent upon the stimulus of the sense organs of the individual. Although some objective tests provide information which substantiates subjective appraisals of color, texture, tenderness, and juiciness, determination of odor and taste in food can not be made objectively.

Subjective evaluation

In subjective scoring methods the qualitative and quantitative aspects of the characteristics under consideration are based on the opinions of judges. Lowe and Stewart (55) classify subjective tests into two categories: (a) preference or acceptance tests and (b) difference or psychometric tests. Because psychometric tests can determine quantitative difference by scoring or rating food quality factors, they are valuable research tools.

Scoring tests. According to Lowe (52), scoring tests are made more frequently than any other sensory tests. Single palatability factors are assigned a numerical rating by the scorer. The scorer is expected to detect differences in the samples, if they exist, and to assign a quantity factor to these ratings.

Paired samples. Cover (22) used paired samples for scoring meat. In this method, the scorer was asked to determine which of two samples was the more tender. A recent experiment by Cover (21) showed trained personnel were able to distinguish successfully between the following components of tenderness--softness, friability, and tenderness of connective tissue. This method of partitioning tenderness into several components seems to offer increased opportunities for relating chemical and physical changes to certain kinds and degrees of tenderness.

Difference tests. Three methods of conducting subjective difference tests were discussed by Peryam and Swartz (71). In the triangle test three samples were presented to the judges at the same time. They were asked to select the odd sample from the other two identical samples. In the duo-trio test, judges were presented a control and then two samples of unknown order. They were asked to pick the sample which was different from the control. In the dual standard test two odor samples were presented to the judges. They were asked to study them and note differences. A second pair of samples was given to the judges and they were matched with each of the first samples. Peryam and Swartz (71) recommended the triangle test for discrimination, the duo-trio test for taste, and the dual standard test for odor.

According to Davis and Hanson (28) considerable information was lost in the use of the triangle test if intensity designation was not made or if the test was utilized only for those judgments in which the odd sample was recognized. They presented a new method of evaluating the results of the triangle test in which intensity designation was required. All judgments were evaluated in terms of an I-value which was directly related to the probability of chance occurrence of the judgment. The inclusion of partially corrected judgments provided for increased efficiency by reducing the number of trials necessary to detect a difference at a given level of significance. Simon, Carroll, and Clegg (80) compared the triangle method with a quality judgment procedure (scoring) in evaluating the effect of degree of finish on differences in quality factors of beef. Although the results of the two procedures were in agreement, they reported that triangle testing was not as sensitive as scoring in evaluating products of a high degree of variability.

Problems inherent in subjective evaluation. Several investigators (7, 47,51) have discussed problems involved in the subjective method of testing. Boggs and Hanson (7) observed that each judge tends to weigh the various factors by his own standards. In some cases, fatigue was found to be a disadvantage, but in meat, it was not necessarily important (51). Psychological and physiological factors have also been shown to influence judges' scoring (55).

The importance of scientific technique for constructing score cards was emphasized by Sweetman (85). Qualities should be selected and weighed according to the investigation being made.

Authorities in the field of taste panel work suggest that equipment and environment be controlled. Air-conditioned rooms were advantageous in preventing odors of paint, coffee, smoke, or other such aromas from interfering with accurate detection of differences in samples (31). According to Foster, Pratt, and Schwartz (33) isolation of the judges gave more accurate results. To assure optimum results, china, silver, and glass must be used; placing the samples on paper dishes was unsatisfactory (70).

Overman and Li (63) recommended that the reliability of the judgments should be checked to obtain maximum validity from taste panel scores. They suggested methods for measuring the consistency and discriminating ability of taste panel members. Despite the limitations, subjective testing is considered essential in determining food acceptability.

Objective evaluation

According to Lowe and Stewart (55), objective tests can be reproduced and are more applicable to the needs of the control laboratory. Subjective ratings of tenderness, juiciness, and color of meat may be substantiated by objective measurements.

<u>Tenderness</u>. Numerous devices for measuring the tenderness of meats have been invented. Noble, Halliday, and Klaas (62) were successful in using the New York Testing Laboratory penetrometer for comparing the tenderness of left and right sides of the same animal. Proctor et al (72) reported a recording strain-gage denture tenderometer. The instrument consisted of a complete set of human dentures. According to initial tests, the machine had good potentialities for aiding in solving the problem of standardization of criteria for tenderness measurements.

Bratzler (11) improved the Warner shearing machine by standardizing the shape and size of the opening and the type of cutting edge. This modified machine, known as the Warner-Bratzler Shearing apparatus, has been widely used for tenderness determinations. Several investigators (1,78) have established a high degree of correlation between taste panel scores for tenderness and shear force readings. Sparing and co-workers (82) determined tenderness in raw and cooked beef muscles with a tenderness press, which was a modification of the Carver juice press. A panel and the Warner-Bratzler shear apparatus were also used to measure tenderness of the cooked meat. Correlations between press and Warner-Bratzler shear were significant.

<u>Juiciness</u>. Development of a method for objective evaluation of juiciness of meats was based on the principle of expressing fluid from meat samples of known weight. In 1934, Child and Baldelli (12) reported an apparatus called the pressometer and standardized a method for determining the percentage of press fluid. Studies (13,29) have shown a correlation between pressometer readings and taste panel juiciness scores.

Tannor, Clark, and Hankins (86) reported the development of a hydraulic press which determined expressible juice content of meat. However, their findings showed no close correlation between results obtained by the hydraulic press method and the taste panel scores for juiciness of beef cooked to an internal temperature of 58°C.

Color. Tappel (87) illustrated the usefulness of reflectance spectrophotometry for measurement and identification of hematin pigments in meats. The entire visible spectra from 400 to 600mu was recorded. He found that hematin pigments have a relatively sharp and characteristic reflectance minima.

Combination subjective and objective evaluation

Perhaps the type of evaluation most widely applicable to all foods is the subjective-objective approach. Lowe and Stewart (55) pointed out that objective tests for organoleptic qualities must measure those characteristics which are correlated with acceptability. A partly subjective, partly objective method for comparing tenderness of different meat samples was described by Lowe (52). It consisted of counting the number of chews necessary to masticate the sample to a predetermined end point. The samples were sliced on a machine so that the fibers were all the same length, and samples of the controlled dimensions were used. Scorers standardized the end point of mastication and determined a specific gradation of their own scores in relation to the number of chews required for complete mastication of the sample. Examples of the use of a combination of subjective and objective methods of evaluation are shown in the research done on tenderness and juiciness (59,77).

METHOD OF PROCEDURE

To compare cooking losses, palatability, and rate of heat penetration, roasts were cooked by two methods under controlled conditions. The conventional roasting method employed by Douglas (30) in a related project has been followed as closely as possible. Standardized procedure for cooking by deep fat immersion was established through preliminary investigations in the laboratory.

Materials Used

<u>Beef roasts</u>

Six pairs of U.S.D.A. Choice grade steer beef rounds, rump on, weighing approximately 65 to 75 pounds per round, were procured through the Michigan State University Department of Animal Husbandry. Six days after slaughter, the semimembranosus muscles were dissected and surface fat was removed. The muscles were trimmed to provide roasts of approximately 1440 grams each, and standardized with respect to linear measurements for length, width, and depth. The samples for roasting were individually wrapped in heavy freezer paper, coded, blast frozen, and stored at -20°C until defrosting prior to cooking. Storage periods ranged from 173 to 189 days. Data relative to weight of rounds, weight of muscles, muscle linear measurements, and trimmed sample weight are shown in Table 14, the Appendix, page 91.

<u>Fat for fryer</u>

Two 50-pound boxes of all-purpose, hydrogenated vegetable fat were obtained from the Michigan State University Food Stores.

Equipment

Most of the equipment used in this study is comparable to that found in institutional kitchens. However, special pieces of equipment were used to facilitate accurate collection of data.

Weighing and measuring. A 4.5-kilogram capacity torsion balance was used to weigh the samples, fat, pans, racks, and drippings to the nearest gram. Total drip obtained from cooking by deep fat immersion was collected in a graduated beaker. Readings were recorded in milliliters and converted to grams.

A device consisting of three rulers was used to measure the length, width, and depth of each sample. Two vertical 18-inch rulers, numbered from the bottom to the top, were connected by a horizontal 24-inch ruler with numbers reading from left to right. The left vertical ruler, secured on a metal foot, could stand alone. The horizontal ruler could be moved up and down; while the right vertical ruler could be moved toward or away from the left ruler. To measure the length, each sample was placed between the vertical rulers so that the rulers touched the meat on both ends at the longest point. For width determination, the rulers were adjusted so they touched both sides of the sample. To measure the depth of the sample, the horizontal ruler was lowered until it touched the meat. Each time the ruler was adjusted until it matched both vertical rulers at the same inch marking. Measurements for width and depth were recorded at the anterior, middle, posterior, and maximum portions of the sample.

A large pyrex cylinder, two 1000-milliliter graduated cylinders, a rubber hose, a clamp, and a 12-inch thermometer with a temperature range of -20 to 100°C were used for volume measurements.

The smoke point of the fat was measured with a 9-inch thermometer, with a temperature range of -10 to 250°C, positioned in a sillimanite casserole, 3.5 inches in diameter, containing 100 grams of fat.

An 8-point Brown Electronik Potentiometer High Speed Multiple Point Recorder was used to record data relevant to time-temperature relationships of the roasts throughout the cooking and cooling periods, the internal oven temperature, and the temperature of the frying medium.

Oven roasting. Each conventionally roasted sample was placed on a trivet, 14.5-inches long by 10.25-inches wide, with one-half inch legs, in a standard aluminum roasting pan, 17.25-inches long by 11.25-inches wide by 2.25-inches deep. The lower deck of a 2-deck, thermostatically controlled Hotpoint roasting and baking oven, Model No. HJ225, was used throughout the study for these samples.

Roasting in deep fat. Samples immersed in deep fat were placed in a single, full size wire fryer basket, 11-inches long by 11-inches wide by 4.75-inches deep. A thermostatically controlled Hotpoint commercial electric deep fat fryer, Model No. HKG4, was used to cook samples in hot fat.

Slicing. Samples for taste panel scoring were cut ¼-inch thick on a Hobart electric slicer, Model No. 410.

Objective testing. A Beckman zeromatic pH meter and a Bausch and Lomb spectronic 20 colorimeter with reflectance attachment were used to determine the acidity and per cent reflectance of both raw and cooked samples. Tenderness and juiciness of cooked roasts were evaluated by a Warner-Bratzler shear apparatus, and a Carver press machine, respectively.

Preliminary Investigations

Before the actual experiment began, a series of cuts from the top round of beef, resembling the test samples, were conventionally roasted and cooked by deep fat immersion. Preliminary investigations served to establish the approximate amount of fat required for immersion of the sample, a temperature for cooking in hot fat, and a technique for collection of the drippings. Methodology for the preparation of samples for objective testing was developed. Samples from the roasts were used for preliminary taste panel instruction.

Amount and re-use of fat

Cuts of beef from the top round, similar in weight and shape to the actual test samples, were used to determine the quantity of fat necessary to submerge the meat. In preliminary trials, fat was re-used a total of 6 times. To insure that the smoke point was safely above the desired cooking temperature, smoke point determinations were made before and after each cooking period. Since re-use of the fat showed no unfavorable results, this procedure appeared to be of no disadvantage for this study.

Determination of fat temperature

Roasts were immersed in fat at temperatures ranging from 100 to 120°C and compared with oven roasts. At lower temperatures, the surface of the meat was a gray-brown color, not the rich-brown characteristic of a conventionally roasted product. At higher temperatures, the cuts shrank considerably and a thick, hard crust formed on the surface. Temperatures between 110 and 118°C seemed most desirable. After further work, it was decided that a fat temperature of 115°C gave a product which most nearly resembled an oven roast.

The contact heat, for roasts cooked at temperatures of 115°C in fat and 149°C in air, was considered comparable by an engineering consultant. When a product is cooked in heated air there is a stationary layer of air surrounding the surface, which acts as an insulator. This insulator, therefore, slows heat transfer. Thus, a conventional oven heated to 149°C is approximately equivalent to 116°C contact heat. The procedure used for equating contact heat for beef roasts cooked in fat and in air is given in the Appendix, page 92.

Collection of drippings

Drippings obtained from conventionally roasted and cooled samples were weighed to the nearest gram. For samples cooked in fat, drip obtained during the specified cooling period was poured into a 125-milliliter graduated beaker and the pan scraped clean with a rubber scraper. The beaker was covered with Saran, refrigerated overnight, and drip separated from the cooking fat was added the following day.

Drippings were observed at the bottom of the fryer when samples were cooked in hot fat. Thus, an attempt was made to remove drippings from the cooking medium itself. The first portion of fat was strained, through 4-layers of fine cheesecloth, into a small container and the rest into a larger container. After overnight refrigeration, fat from the small container was removed until there was approximately a ½-inch layer of solid fat remaining above the liquid. The contents were then melted, poured into a 1000-milliliter glass cylinder, and refrigerated. When the drip and cooking medium had separated, the hardened fat was removed. The liquid portion was combined with drippings collected from the cooling period of the previous day and milliliters of total drip were recorded.

Preparation of samples for objective testing

Raw samples for objective testing were obtained from a ½-inch slice removed from the posterior end of each roast. The location from which cooked samples were taken is shown in Figure 1.

Methodology for objective measurements was developed as follows:

pH. For the determination of pH, 20 grams of defrosted raw sample or 20 grams of cooked sample were combined with 100-milliliters of distilled water and blended for three minutes in a Hotpoint electric blender. Slurries were strained through a fine sieve into two small beakers. This amount was sufficient to permit duplicate readings for each sample.

Color reflectance. Raw and cooked samples of beef were shredded on a coarse grater and tightly packed into a glass cup, 1.75-inches in diameter and 1-inch high. Per cent color reflectance was recorded at wavelengths of 415, 445, 475, 505, 535, 545, 565, 595, 625, 655, and 685mu which were standardized against a magnesium carbonate block.

Press fluid. A sharp knife was used to remove the outside slice from the cooked roast. The roast was placed on the electric slicer and the cut surface straightened by removing a second thin slice. Two ¼-inch slices were removed from this straight edge, wrapped in Saran, coded, frozen, and stored at -20°C. Storage periods for these objective samples ranged from 3 to 23 days. Upon completion of the experiment, all wrapped samples were defrosted at room temperature (23 to 24°C) before press fluid determinations were made.

Shear. After samples for press fluid determination were removed, a distance of 3 inches was measured and another cross-grain cut was made.

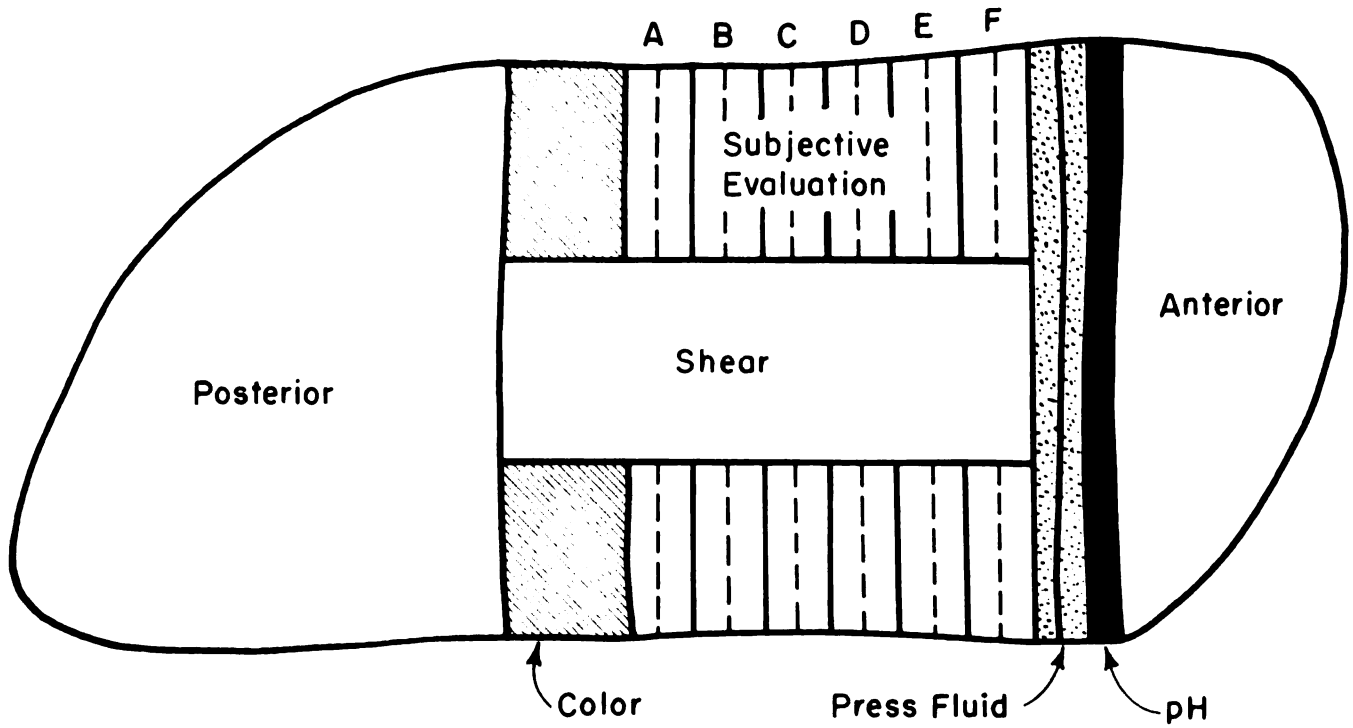

Figure 1. Location of samples for objective and subjective evaluation of cooked roasts.

A core, 1-inch in diameter, cut parallel to the fiber axis, was removed from the center of each muscle. Each core was wrapped in Saran, coded, frozen, and stored at a temperature of -20°C until completion of the experiment. Storage periods for cores ranged from 3 to 23 days. Wrapped cores were defrosted at room temperature (23 to 24°C) before shear tests were made.

Preparation of samples for subjective testing

The section of the roast from which a shear core had been removed was used for subjective scoring. The electric meat slicer was set at 12 so that slices were approximately $\frac{1}{4}$-inch thick. Two slices from a conventionally roasted sample and two slices from a sample cooked in deep fat were arranged on coded plates, covered with Saran, and refrigerated 3 to 4 hours at 4°C. One hour before tasting, the samples were removed from the refrigerator and brought to room temperature.

Preliminary taste panel

Slices of beef, from one oven roast and from one sample cooked in deep fat, were presented to a panel of six judges. The evaluators were asked to consider each sample without reference to the other. Score sheets were discussed. Palatability factors to be scored were: aroma, color, texture, flavor, juiciness, softness, friability, residual tissue, and tenderness. A copy of the score sheet is included in the Appendix, page 94.

For judgments regarding residual connective tissue and tenderness, the panel was asked to cut a .50-inch square piece from a slice from each cooking method. To establish a "chew range" table for each panel member, judges were instructed to chew each .50-inch sample until it was completely masticated. They recorded the number of chews for each sample and also assigned each sample a numerical tenderness score. An individual "chew range" table, based on the number of chews and the scores recorded for these samples, was developed for each judge. These tables were then used by the judges for scoring samples for tenderness throughout this project.

Preroasting Preparation

Methods for the cooking of samples were assigned according to a randomized arrangement of left and right muscles from the six pairs of rounds. Cooking periods were scheduled twice weekly for a period of three weeks. The preparation for each day of cooking included one sample roasted in the oven and one sample cooked in the deep fat fryer.

The sample

Wrapped raw roasts were defrosted for 48 hours in a reach-in refrigerator at 4°C. At the end of the defrosting period, raw samples were unwrapped, a posterior portion was removed for objective determination of pH and color reflectance, and the gram weight of the remaining sample was recorded. Linear measurements were taken according to procedures established during preliminary studies. Volume was obtained by the displacement method in 10 to 15°C water.

Each of the samples cooked conventionally was placed on a trivet in a shallow aluminum roasting pan. Samples cooked by immersion in deep fat were placed in the full size fryer basket.

Three potentiometer leads, for recording data pertaining to time-temperature relationships, were positioned in the sample as follows:

a with depth equal to the radius at maximum thickness, b 3/4-inch from the surface, and c ¼-inch from the surface (Figure 2).

Cooking media

For the conventional roasting method, the oven was preheated to 149°C. A potentiometer lead was centrally mounted in the oven to record the heated air temperature throughout the cooking period.

For the deep fat immersion method, the hydrogenated fat was placed in the fryer and preheated to 115°C. At the beginning of each cooking period, fresh fat was added to fill the fryer to the initial weight of the previous cooking. In addition, in order that all samples be submerged, extra fresh fat was added when necessary and the amount recorded. Two potentiometer leads were placed in the cooking medium, one approximately one-inch from the side of the container and the other centrally positioned. A 100-gram sample of fat was removed for pre-cooking smoke point determination.

Throughout the cooking period the temperatures of both media were adjusted to maintain controlled temperatures of 149°C for air and 115°C for fat.

Cooking Process

Conventional method

When the internal temperature of the raw defrosted sample reached 6°C, the sample was placed in the preheated oven. When all potentiometer leads which were positioned in the sample had reached a minimum internal temperature of 80°C, the roast was removed from the oven and cooled at room temperature to 70°C. Then the thermocouples were removed and the roast was allowed to stand for 15 additional minutes.

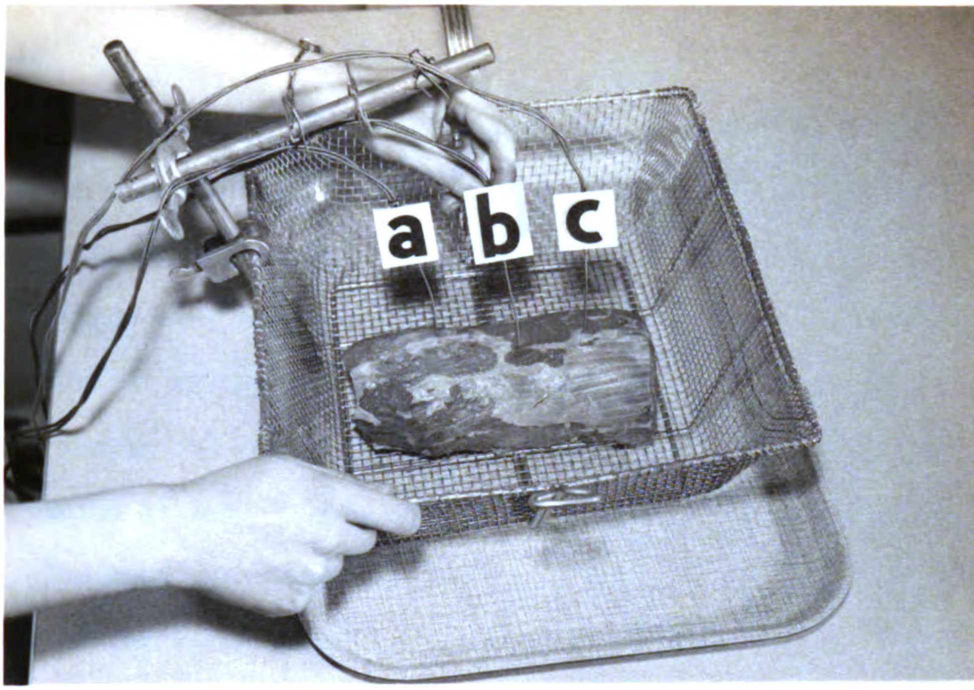

Figure 2. Positioning potentiometer leads: a = radius, b and c = 3/4- and 1/4-inch from surface

Figure 3. Immersing sample in 115°C fat

Deep fat method

The raw sample stood at room temperature until it reached 6°C before it was immersed in the hot fat (Figure 3). When all potentiometer leads positioned in the roast had reached a minimum internal temperature at 80°C, the basket and sample were removed from the cooking medium and suspended over the fryer for two minutes to permit the fat to drain from the meat. Then the cooked sample and basket were placed in a shallow roasting pan; the roast was cooled at room temperature to 70°C before the thermocouples were removed. The meat was allowed to cool an additional 15 minutes. A 100-gram sample of the cooking medium was removed for post-cooking smoke point determination.

Handling the Cooked Sample

Part of the data was recorded before the roasts were refrigerated. However, the major portion of the data was collected on the following day.

Treatment of roasts before chilling

At the end of the cooling period, sample weight, linear measurements, and volume by displacement in 45 to 50°C water, were recorded. Then the roast was wrapped in Saran, coded, and refrigerated at 4°C.

Drippings obtained from conventional roasts were recorded. The total weight of the roasting pan, the trivet, and the roast drippings was recorded. Weight of the total drip in grams was determined by subtracting the known pan and rack weight from the total weight.

For the samples cooked in deep fat, drippings obtained during the cooling period were scraped into a graduated beaker, covered with Saran, and refrigerated at 4°C.

Treatment of roasts after chilling

The day after the roasts were cooked, samples for objective testing and for subjective scoring were removed according to procedures described under Preliminary Investigations.

Drippings in the fat were collected according to the method developed in preliminary studies, and combined with pan drippings which had been refrigerated. Total drip, recorded in milliliters, was converted to ounces and then to grams.

Evaluation of Roasts

Palatability characteristics of the roasts were evaluated subjectively. Appearance and flavor of drippings from each sample were subjectively judged. Acidity, color reflectance, juiciness, and tenderness were objectively measured. Data pertaining to rate of heat penetration for the roasts was studied.

Subjective testing

Samples from roasts representing each cooking method were presented to each of the six panelists. A particular judge was always served cuts from the same relative position of the roast. Samples, which had been refrigerated, were allowed to stand at room temperature for an hour prior to tasting. Glasses of water at room temperature were provided. The panel was seated in an arrangement that discouraged the members from exchanging comments or facial expressions.

The panel scored the samples for aroma, color, texture, flavor, juiciness, softness, friability, residual connective tissue, and tenderness. Scoring was based on a seven point scale. A score of 1 indicated unacceptable quality; a score of 7 depicted excellent quality. Descriptive terminology for each numerical score was considered in assigning a score for each palatability factor. Comments of the judges were summarized and applied to the interpretation of the data.

Objective testing

Color reflectance and pH of raw samples were measured on the day of cooking. Cooked samples were tested for pH and color reflectance on the day after cooking.

pH. Slurries were prepared as previously described. Duplicate readings, taken according to standard laboratory procedure, were averaged. Change in pH between the raw and the cooked sample was calculated for each replication.

Color reflectance. Per cent color reflectance at eleven wavelengths, ranging from 415 to 685mu, were recorded for raw and cooked samples of each replication. Duplicate readings for each sample were totaled and averaged. Mean readings for replications were averaged within methods for each wavelength and differences between methods of cookery were determined.

Press fluid. The Carver press was used to determine juiciness of the cooked roasts. Two defrosted samples, each weighing 12 to 14 grams, were obtained from each replication, placed between felt pads, and subjected to a pressure of 15,000 pounds per square inch for 10 minutes. After pressing, samples were separated from the pads and reweighed. Percentage of press fluid was calculated by dividing the difference between the initial and pressed weights by the initial weight of the sample.

<u>Shear</u>. Tenderness was objectively measured by the Warner-Bratzler shear apparatus. This machine measures the force in pounds required to cut through a cylinder of muscle one inch in diameter. Five shear readings were taken from each defrosted core. These readings were totaled and averaged for each roast.

<u>Cooking losses</u>. Total cooking, drip, and volatile losses were calculated for each roast and these values were converted to percentages based on the raw weight of the sample. Volume loss was changed to percentage of initial sample volume.

Heat penetration

Throughout the cooking and cooling periods, progressive time-temperature relationships at three depths of the roasts were recorded on the potentiometer. Mean progressive time-temperature relationships for three depth measurements (radius, 3/4-inch, and ¼-inch from the outer surface) were determined for each method of cookery. Rate of heat penetration in minutes per °C temperature rise was calculated.

Analysis of the data

Objective data pertaining to total cooking loss, drip loss, volatile loss, volume loss, shear, and press fluid were statistically evaluated by analysis of variance to determine differences attributable to method of cookery. This statistical measure was also used to evaluate differences due to method of cookery for changes in pH and color reflectance.

To minimize variance due to judges, scores for each replication were averaged for each palatability characteristic evaluated. To determine differences due to cooking method, analysis of variance, based on mean taste panel scores, was computed for each palatability factor.

Correlation coefficients were determined for all possible combinations of tenderness, softness, friability, residual tissue, and shear measurement. In addition, per cent total cooking loss and subjective juiciness were correlated.

RESULTS AND DISCUSSION

In this study the effects of conventional oven-roasting and of cooking by deep fat immersion on semimembranosus muscles from paired U.S.D.A. Choice steer beef rounds were observed. Data pertaining to rate of cooking, cooking losses, and palatability were collected to determine differences attributable to cooking method.

Mean progressive time-temperature relationships were compared to determine differences in rate of heat penetration due to cooking medium. Changes in pH brought about by cooking were recorded. Changes in the smoke point of the hydrogenated fat, which resulted from re-use of the medium, were determined.

Analyses of variance, correlation coefficients, and subjective and objective evaluations were considered in the interpretation of results for cooking losses and palatability of the roasts.

Heat Penetration

Due to difficulty in obtaining accurate potentiometer recordings during one day of cooking, results and discussion of data pertaining to rate of cooking are based on five replications for each method. Potentiometer leads were placed at three depths from the surface of the sample: 1/4-inch, 3/4-inch, and 1 1/2-inches (radius). The lead positioned with depth equal to the sample radius was used to determine the end of the cooking period for both methods.

Average progressive time-temperature relationships during the cooking period for three sample depths and two methods are shown in Figure 4. The initial temperature of all roasts was 6°C at the 1 1/2-inch depth. Initial temperature averages for the 3/4- and 1/4-depths were 7 and 8°C, respectively. All curves for roasts cooked in deep fat were steeper and shorter than the comparable curves for oven roasts. The temperature rise of roasts cooked in fat increased steadily and rapidly throughout cooking. Although the rise in temperature for oven roasts was much slower than for deep fat roasts, the rate of rise was steady until an internal temperature of 55°C was reached. As the degree of muscle coagulation increased, the rate of temperature rise decreased. Roasts cooked in the oven required nearly twice as long to reach the desired end cooking temperature as those cooked in fat. The average total cooking time was 138.2 minutes for oven-roasted samples and 73.4 minutes for samples cooked by deep fat immersion. These results are similar to findings reported by Visser et al (92).

As was expected, the internal temperatures of the roasts at depths of 1/4- and 3/4-inch from the surface exceeded the internal temperature at the radius. End cooking temperatures for these locations varied from 84 to 92°C at the 1/4-inch depth and from 80 to 90°C at the 3/4-inch depth for the oven-roasted samples. Variations in end cooking temperature for samples cooked by deep fat immersion were from 88 to 98°C and 84 to 88°C for the 1/4-inch and 3/4-inch positions, respectively. Inherent differences in the samples, changes in linear measurements brought about by evaporation and coagulation of the tissue, and experimental error in the placement of the potentiometer leads appeared to contribute substantially to variations within replication.

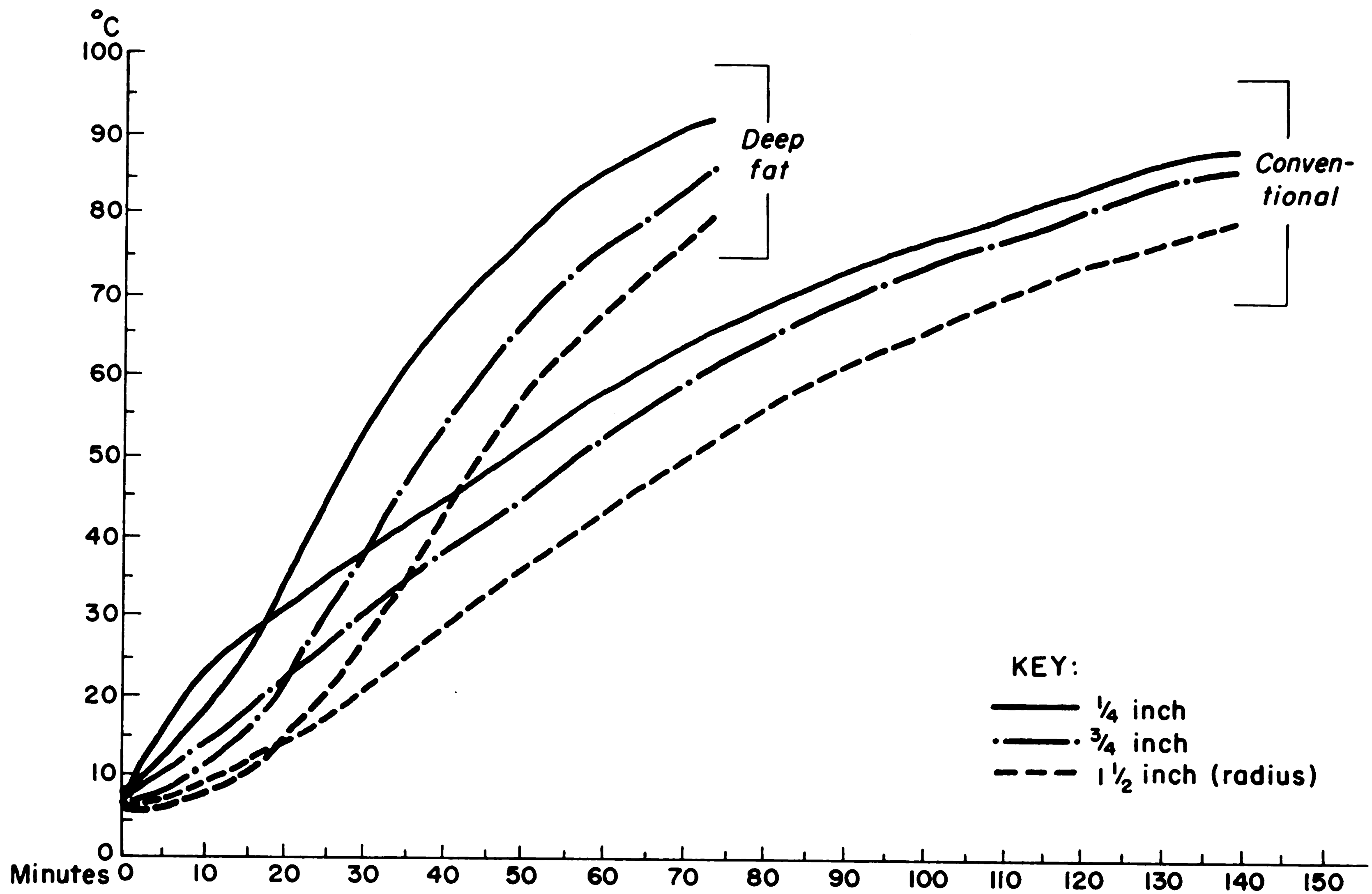

Figure 4. Average time-temperature relationships during cooking for three sample depths for two methods.

After cooking was terminated, the roasts were allowed to stand at room temperature until the temperature at the radius had cooled to 70°C. The interior temperature rise of roasts cooked in deep fat ranged from 3 to 7°C, while the rise in temperature of oven roasts varied from 0 to 1°C. Deep fat samples were representative of very well-done meat whereas the interior of conventionally roasted samples was frequently described as atypical for well-done beef.

Progressive changes in the average rate of heat penetration during cooking, expressed as minutes per degree Centigrade rise at 10-degree intervals from 20 to 80°C, for three sample depths and two cooking methods are illustrated in Figure 5. Changes in the rate of heat penetration for each replication are given in Table 15, the Appendix.

These heat penetration curves indicated that, although the sample contact heat for both methods was comparable (see page 92, the Appendix), the transfer of heat from the cooking medium to the sample was more rapid in fat than in air. This result is in accord with findings reported by Visser et al (92).

When hydrogenated fat is used as a cooking medium, it becomes a liquid composed of molecules having free movement over themselves, but without a separative tendency like that of gas molecules in air. Because of this physical characteristic, fat achieves closer contact with the meat than is possible with air and the thickness of the stationary layer of air surrounding the sample is minimized. In addition, fat molecules carrying heat energy are in greater concentration at the fat/stationary air interface than is possible with gas molecules at the heated air/stationary air interface. The insulating effect of the stationary air layer surrounding the sample is

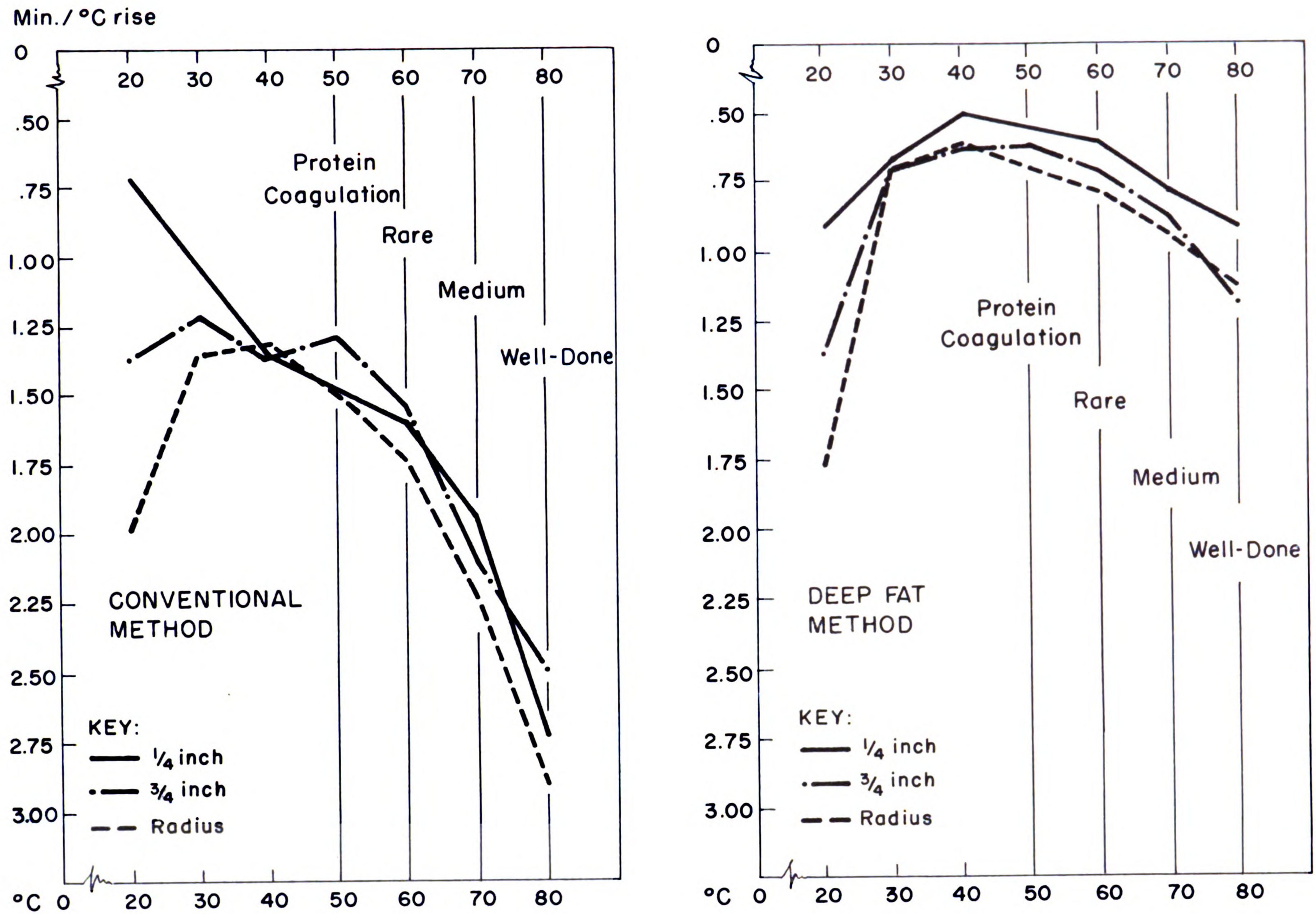

Figure 5. Average rate of heat penetration: Min./°C rise for three sample depths for two cooking methods.

reduced and the heat energy is transferred to the surface of the meat more efficiently.

The heat penetration curves at all sample depths measured in roasts cooked in deep fat were similar in shape. Time required to raise sample temperature one degree Centigrade was always least at the 1/4-inch depth. For the major portion of the cooking period, minutes per degree Centigrade rise for the 3/4-inch location was only slightly less than for the radius of the sample. Rate of heat penetration for all depths increased rapidly until an internal temperature of 40°C for the 1/4-inch depth and 30°C for the 3/4-inch and radius depths had been reached. At internal temperatures from 40 to 80°C the rate of heat penetration at the 1/4-inch depth showed a gradual decrease. Although the rate of heat penetration for the other two curves continued to rise up to temperatures of 50°C for the 3/4-inch depth and 40°C for the depth at the radius, the rate of increase was much slower. After these temperatures were attained, the rate of heat penetration for these curves gradually decreased throughout the remainder of the cooking period.

Variation in the heat penetration rate for all sample depths was more pronounced in oven roasts. At the 1/4-inch depth the rate of penetration decreased steadily as the temperature of the roast increased. At the 3/4-inch depth the rate of penetration increased until an internal temperature of 30°C was reached, decreased slightly between 30 and 40°C, increased slightly between 40 to 50°C, and then decreased gradually during the remainder of the cooking period. At the depth of the radius the rate of penetration increased sharply to an internal temperature of 30°C, increased only slightly from 30 to 40°C, and then decreased sharply during the remainder of the cooking period.

According to Lowe (52), interior temperatures suggested by Sprague and Grindley as representative of rare beef range from 55 to 65°C, that which has reached inner temperatures of 65 to 70°C may be called medium-done, while beef which has attained a temperature of 70 to 80°C may be termed well-done. To compare the rate of heat penetration for the two cooking methods, temperatures of 50, 60, 70, and 80°C have been chosen as typical of the following degrees of doneness: muscle coagulation, rare, medium, and well-done. Figure 5 illustrates the comparative changes in minutes per degree Centigrade rise between stages of doneness for the two cooking methods for the three sample depths.

The rate of heat penetration for roasts cooked in air or in fat decreased as roasts approached the rare stage. Since both protein coagulation and evaporation are endothermic processes, less heat was available to raise the temperature of the tissue. However, for each sample depth measured the rise in temperature for meat cooked in hot fat was faster than that of the oven-roasted samples. Table 1 presents the rate of accelerated cooking for deep fat roasts as compared with oven roasts for three sample depths.

Table 1. Relation between rates of heat penetration for cooking in air and in fat, three sample depths, at four degrees of doneness.

Degree of Doneness	Accelerated Cooking Rate for Deep Fat Samples		
	1/4-inch	3/4-inch	Radius
Muscle coagulation	2.69	2.11	2.13
Rare	2.67	2.20	2.20
Medium	2.47	2.41	2.36
Well-done	2.95	2.10	2.57

Table 1 shows that as the degree of doneness progressed, the degree of protein denaturation and evaporation appeared to affect the rate of heat penetration. This in turn influenced time required for the center of the roasts to reach an internal temperature of 80 °C.

Meat has an inherent capacity for absorbing heat. During cooking heat is carried to the interior of the meat by conduction. It seems likely that the shorter time required for roasts cooked by deep fat immersion may be due, in part,to the faster and more efficient transfer of heat provided by the fat medium. The farther the raw tissue is from the source of heat energy, the longer the time required to raise the internal temperature. As the depth of coagulated protein increased, the rate of heat penetration appeared to decrease. From these data, one might conclude that the rate of heat penetration in cooked tissue may be slower than in raw tissue.

pH

Determination of pH for raw and cooked samples, based on the mean of two readings, and the change in pH for six replications for each cooking method are presented in the Appendix, Table 16. The pH of raw roasts used for both cooking methods ranged from 5.4 to 5.7. In all cases cooked roasts were slightly more alkaline than raw roasts. The pH of conventionally roasted samples varied from 5.6 to 5.9, whereas the pH values for samples cooked in deep fat ranged from 5.7 to 5.9. An analysis of variance of the changes in pH brought about by cooking were not significant for method.

Panel evaluations of cooked roasts indicated that, irrespective of cooking method, all samples were judged slightly tough. According to Lowe (52), toughness of cooked beef is maximum at a pH of 5.0 to 6.0. It seemed likely that tenderness of roasts was affected, in part, by the pH of the sample.

Smoke Point

A lowering of the smoking temperature is among the changes which occur in fats during cooking. Results of smoke point determinations of the cooking medium indicated that during re-use the smoking temperature of the hydrogenated fat was lowered only slightly. Smoke points ranged from a temperature of 221°C at the beginning of the experiment, to a temperature of 217°C at the completion of the study. The change in smoking temperature, before and after each cooking period, was not consistent and varied from 0 to 2°C.

Cooking Losses

Data pertaining to total, drip, and volatile losses were converted to percentages of raw sample weight. Volume loss was changed to percentage of initial sample volume. Per cent total, drip, volatile, and volume losses for six replications for each cooking method are recorded in Tables 17 and 18, the Appendix. Average percentage values for cooking and volume losses for samples cooked by conventional roasting and by deep fat immersion are shown in Table 2.

Table 2. Mean per cent cooking and volume losses of six replications for two methods of cookery.

Losses	Method	
	Conventional	Deep Fat
Total cooking	33.14	38.24
Drip	2.04	1.23
Volatile	31.10	37.01
Volume	31.65	44.91

Analyses of variance were applied to the percentage data to determine differences attributable to cooking method. Highly significant differences were found for all types of losses. A summary of these analyses is presented in Table 3.

Table 3. Analyses of variance of cooking and volume losses for two methods of cookery.

Source of Variance	D. F.	M. S. Values			
		Total	Drip	Volatile	Volume
Total	11				
Method	1	78.490**	1.920**	105.030**	527.880**
Error	10	1.716	.190	2.577	22.203

**Significant at the 1% level of probability.

Total cooking losses

The average total cooking loss was 33.14 per cent for oven roasts and 38.24 per cent for samples cooked in deep fat. Total losses for roasts cooked in deep fat were significantly greater than for oven roasts (Table 3). A comparison between total cooking losses and subjective juiciness scores revealed a negative correlation (r = -.786) significant at the 1% level of probability. These results are in accord with findings reported by Harrison (40).

Drip losses

Mean percentage values for drip losses were 2.04 and 1.23 for oven-roasted samples and for samples cooked by deep fat immersion, respectively. Analysis of the data showed that the greater amount of drip obtained from oven roasts was significant at the 1% probability level. However, mean juiciness scores and mean press fluid values indicated that oven roasts were juicier than samples cooked in deep fat.

Volatile losses

Average volatile losses for oven roasts and for samples cooked by deep fat immersion were 31.10 and 37.01 per cent, respectively. Analysis of variance for these data revealed that volatile losses were significantly greater (1% level of probability) for samples cooked in fat than for samples cooked in air.

Volume losses

Mean volume loss for oven roasts was 31.65 per cent compared with 44.91 per cent for deep fat samples. Statistical analysis of percentage values indicated that volume losses for oven roasts were significantly less (1% level of probability) than comparable losses for the deep fat samples.

Average percentages for volume loss, changes in linear measurements, and total weight loss for each method of cookery are given in Table 4.

Table 4. Mean per cent volume loss, changes in linear measurements, and total weight loss for two methods of cookery.

	Method	
	Conventional	Deep Fat
Volume loss	31.65[1]	44.91
Shrink in length	1.59	7.47
Shrink in width	16.31	20.61
Gain in depth	10.87	19.23
Total weight loss	33.14	38.24

[1]Averages based on six replications.

During cooking meat shrinks along the length of the fibers and in width but may gain in the third dimension until cooked extremely well-done. According to Lowe (52), the shrink in volume for muscles of beef round is never as great as loss in weight. While data from this limited study for conventionally roasted samples are in accord with findings reported by Lowe, results for samples cooked in 115°C fat do not support this premise.

Palatability

Aroma, color, texture, flavor, juiciness, and general tenderness were the palatability characteristics judged in studying the effects of conventional oven-roasting and of cooking by deep fat immersion. Tenderness was partitioned among several components--softness, friability, and residual connective tissue (21)--to determine whether these factors could be distinguished. Factors were scored according to a scale of 1 to 7, or unacceptable to excellent quality. For each replication, judges scores were averaged for each characteristic evaluated. Average palatability scores for each replication appear in Table 19, the Appendix.

Analysis of variance, based on mean taste panel scores for each method of cooking, was computed for each palatability factor. Grand averages, based on six replications for each method of cooking, for each palatability characteristic evaluated are summarized in Table 5.

Table 5. Average palatability scores[1] of six judges for six samples for two methods of cooking.

Palatability Characteristic	Method of Cooking	
	Conventional	Deep Fat
Aroma	5.0	5.0
Flavor	4.7	4.5
Color	4.5	4.9
Texture	4.5	4.2
Juiciness	4.4	3.7
Softness	4.3	4.4
Friability	3.6	3.7
Residual Tissue	4.7	4.8
General Tenderness	4.3	4.5

[1]Highest possible score, 7 points.

Aroma and flavor

Aroma and flavor of cooked meat are important factors in product acceptability. The average aroma scores for the two cooking methods were identical. In addition, aroma was scored higher than any other palatability characteristic. This score of 5.0 represents good, full aroma. Descriptive terms checked by the judges ranged from a rich and meaty to a fair, faint odor.

According to taste panel judgments, the flavor of the samples was predominantly a faint to full, good flavor. Adjectives used to describe the samples included very meaty, good, fair, and in a few instances, bitter or unpleasant. Judges indicated only slight preference for the oven-roasted samples.

The analyses of variance of aroma and flavor scores are shown in Table 6.

Table 6. Analyses of variance of aroma and flavor scores for two methods of cooking.

Source of Variance	D. F.	M. S. Values	
		Aroma	Flavor
Total	11		
Method	1	.000	.040
Error	10	.046	.055

These analyses showed no significant differences attributable to cooking method for either aroma or flavor.

Aroma, flavor, and appearance of the drip from each cooking method was subjectively evaluated by the investigator. Flavor of the rich-brown drip from oven roasts was described as strong, full, and slightly charred. Drip from samples cooked in hot fat was termed very good, full in flavor, pleasant in aroma, and wine-brown in color.

Color and texture

The external appearance of roasts cooked in the oven at 149°C or in deep fat at 115°C was fairly similar. However, the surface of beef cooked by deep fat immersion was not quite as rich-brown as that characteristic of oven roasts. Visser et al (92) reported that the surface of meat cooked in 100 or 110°C fat was a gray-brown color.

In three instances, judges noted that the samples cooked in hot fat were crusty and they commented on the strong fat flavor of the crusty area. It was interesting to observe that crustiness seemed to increase as the experiment progressed. Possibly, re-use of the fat was a factor. On one occasion, panel members remarked about the crust on an oven-roasted sample. The flavor of this browned area was acceptable.

Samples cooked in deep fat were more representative of well-done meat, although appearance score averages for both treatmenst depict a medium, brown color. Judges frequently described conventionally roasted samples as pinkish-brown, not typical of beef cooked to 80°C. Samples cooked by deep fat immersion were light gray to grayish-brown.

Large areas of the slices from both cooking methods became highly iridescent and/or mottled after exposure to the air. Masuda (59) also noted that judges described many of the samples from the top round, sirloin butt, and rolled rib roasts as iridescent.

Taste panel members scored the texture of conventionally roasted samples slightly higher than those cooked in hot fat. Score averages indicate a fair to good texture. One judge consistently described samples cooked by both methods as spongy, slightly coarse, and stringy. In several instances, another judge noted that oven-roasted samples were porous in a few areas.

The analyses of data pertaining to color and texture, Table 7, showed no significant difference in color or texture scores attributable to cooking method.

Table 7. Analyses of variance of color and texture scores for two methods of cooking.

Source of Variance	D. F.	M. S. Values	
		Color	Texture
Total	11		
Method	1	.410	.300
Error	10	.096	.082

Tappel (87) reported reflectance spectrophotometry useful in measuring hematin pigment changes in the cooking of beef. Mean per cent color reflectance readings for roasts of both cooking methods from this experiment appear in the Appendix, Table 20. Typical spectra of the roasts of both cooking methods are illustrated in Figure 6. Spectral curves for the raw and cooked samples are approximately the same for both cooking treatments. All raw samples showed a strong peak at 535 to 565mu and a less pronounced peak at 655mu. Spectra of cooked samples exhibited a strong peak at 545mu. This latter finding is in agreement with Tappel (87) who reported a relatively sharp and characteristic reflectance spectra minima at 547mu for hematin pigments of cooked beef. He characterized the brown pigments of cooked beef as mixed denatured globin nicotinamide hemichromes.

Table 8 presents the analysis of variance of the changes in per cent color reflectance brought about by cooking for two methods of cookery.

This analysis indicated no significant difference in the change in color reflectance between raw and cooked samples due to method of cooking.

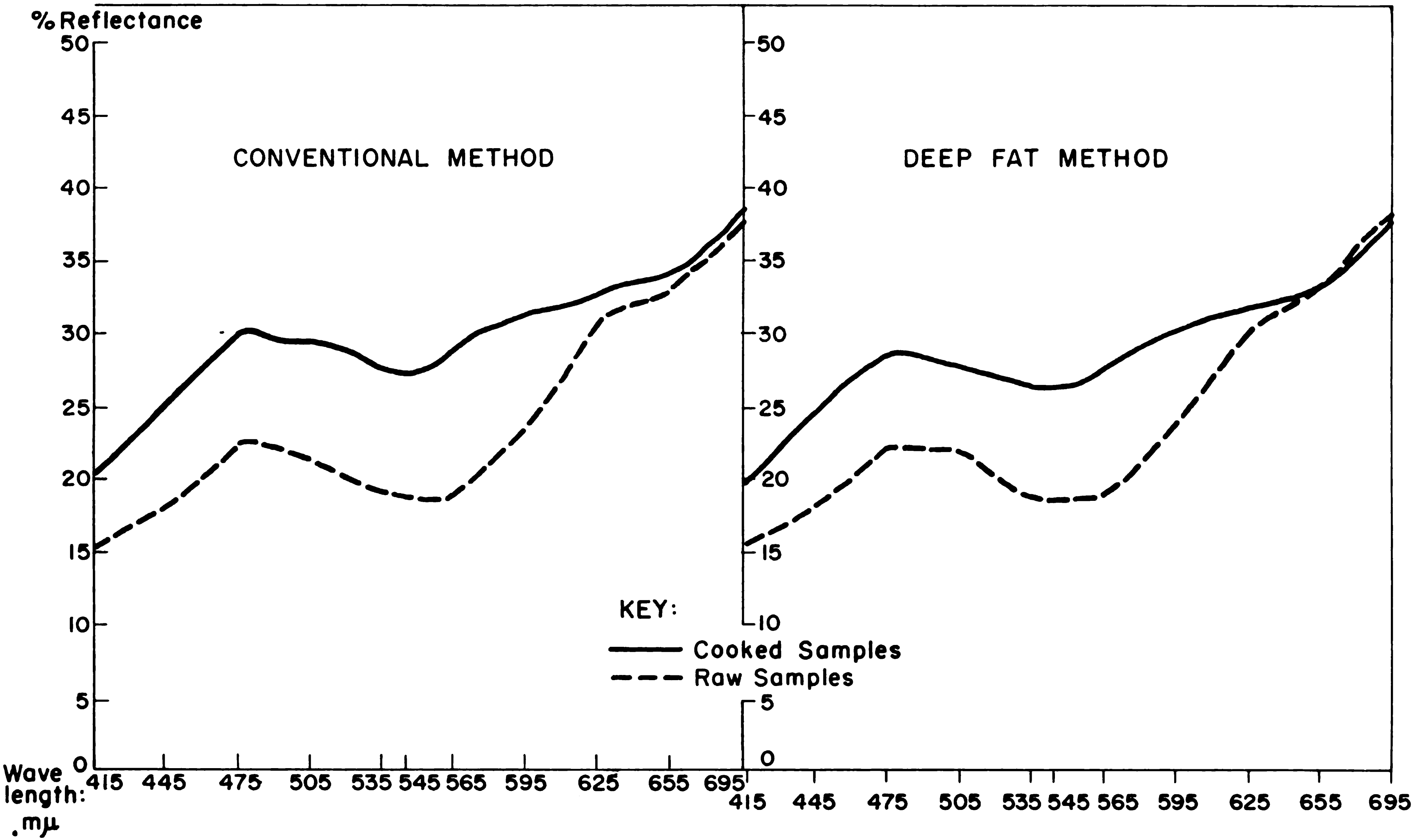

Figure 6. Reflectance spectra of beef: raw and cooked samples of roasts from two cooking methods. (Average of six replications; two readings per replication.)

Table 8. Analysis of variance for changes in per cent color reflectance brought about by two methods of cooking.

Source of Variance	D. F.	M. S. Values % Color reflectance
Total	21	
Method	1	9.820
Error (WL x M)	20	10.545

Juiciness

Average press fluid yields of cooked samples for each replication appear in Table 21, the Appendix. The grand averages for juiciness scores and mean per cent press fluid yields are shown in Table 9.

Table 9. Average juiciness scores and press fluid yields.

Cooking Method	Juiciness Score[1]	% Press Fluid
Conventional	4.4	38.72
Deep fat	3.7	35.56

[1]Highest possible score, 7 points.

For both subjective and objective evaluations, conventionally-roasted samples were juicier than those cooked in deep fat. A positive correlation ($r = .758$), significant at the 1% level of probability, was found between juiciness scores and press fluid yields. Irrespective of cooking method, the taste panel frequently described the cooked samples as dry or neither dry nor juicy. These observations are similar to findings reported by Visser et al (92).

The analyses of variance of juiciness scores and press fluid yields for two methods of cooking are presented in Table 10.

Table 10. Analyses of variance of juiciness scores and press fluid yields for two methods of cooking.

Source of Variance	D. F.	M. S. Values	
		Juiciness Score	Press Fluid
Total	11		
Method	1	1.400**	30.083**
Error	10	.139	1.528

**Significant at the 1% level of probability.

These analyses showed highly significant differences attributable to method of cooking for both juiciness and press fluid yields. These results do not support findings from a study reported by Harrison (40).

Tenderness

General tenderness was based on the number of chews required to completely masticate a sample of predetermined size. Tenderness was also partitioned as softness, friability, and residual connective tissue. Grand average scores for softness, friability, residual tissue, and general tenderness, and mean shear values for two methods of cooking are shown in Table 11. Average shear force readings of cooked samples for each replication appear in the Appendix, Table 21.

Most often samples were rated as neither hard nor soft. The descriptive terms recorded for friability were slightly to moderately friable. The ease with which muscle fibers broke was readily distinguishable by some judges while other panel members could determine no friability.

Table 11. Average scores[1] for softness, friability, residual tissue, and general tenderness, and mean shear force readings (lb.).

Cooking Method	Soft-ness	Friability	Residual Tissue	General Tenderness	Shear (lb.)
Conventional	4.3	3.6	4.7	4.3	19.36
Deep fat	4.4	3.7	4.8	4.5	18.89

[1]Highest possible score, 7 points.

A score indicative of a small amount of firm to soft connective tissue was frequently checked. According to taste panel evaluations and shear force readings, samples cooked by deep fat immersion were slightly more tender than oven-roasted products. However, the usual description of all samples for both methods was slightly tough.

Harrison (40) reported that her taste panel found meat cooked in fat more tender than oven roasts. However, shear score values were lower for roasts cooked in air. Visser et al (92) concluded that, in general, shear values were a little lower for oven roasts than for those cooked in fat. They found little difference in tenderness scores for samples cooked in air and those cooked in fat at 110°C.

Analyses of variance for softness, friability, residual tissue, general tenderness, and shear force showed no significant differences attributable to cooking method. These analyses are given in Table 12.

The relationship between scores for softness, friability, residual tissue, and general tenderness, and shear measurement was studied. Correlation coefficients for these data are summarized in Table 13.

Table 12. Analyses of variance for softness, friability, residual tissue, and general tenderness scores, and shear force readings for two methods of cooking.

Source of Variance	D. F.	M. S. Values				
		Soft-ness	Fria-bility	Residual tissue	Tender-ness	Shear Force
Total	11					
Method	1	.030	.040	.070	.140	.568
Error	10	.152	.260	.104	.200	.394

Positive correlation, significant at the 1% level, was found between softness/tenderness, friability/tenderness, and softness/friability. Positive correlations, significant at the 5% level, were obtained for residual tissue/tenderness, residual tissue/friability, and residual tissue/softness. The coefficient between residual tissue and tenderness nearly approached significance at the 1% probability level. Correlations for Warner-Bratzler shear/tenderness, Warner-Bratzler shear/friability, Warner-Bratzler shear/softness, and Warner-Bratzler shear/residual tissue were not significant.

Table 13. Correlation coefficients for all possible combinations of softness, friability, residual tissue, and general tenderness scores, and Warner-Bratzler shear measurements.

Relationship	Correlation Coefficients
Softness/Tenderness	.711**
Friability/Tenderness	.838**
Residual tissue/Tenderness	.701*
Warner-Bratzler shear/Tenderness	.077
Softness/Friability	.719**
Residual tissue/Friability	.585*
Warner-Bratzler shear/Friability	-.021
Residual tissue/Softness	.629*
Warner-Bratzler shear/Softness	.103
Warner-Bratzler shear/Residual tissue	-.311

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

SUMMARY AND CONCLUSIONS

The objectives of this study were to secure comparative information concerning the effects of conventional oven-roasting and of deep fat immersion on cooking losses, rate of cooking, and palatability of semimembranosus muscle from paired U.S.D.A. Choice steer beef rounds. A total of six replications for each method of cookery were prepared according to standard procedures developed during preliminary trials.

Semimembranosus muscles were dissected, trimmed, standardized with respect to weight and linear measurements, individually wrapped, frozen, and stored until scheduled for testing. The temperature of the cooking mediums was equated so that the contact heat was considered comparable for samples cooked in air or in fat.

Prior to cooking, each sample was defrosted and potentiometer leads were positioned at three depths; radius at maximum thickness, 3/4-, and 1/4-inch from the surface. Roasts were individually cooked at 149°C in air or at 115°C in fat until all potentiometer leads positioned in the sample had reached a minimum internal temperature of 80°C. Data pertaining to rate of heat penetration for the roasts was studied to determine differences in the rate of heat penetration due to cooking medium. Changes in pH brought about by cooking were recorded. Changes in the smoking temperature of the hydrogenated fat, resulting from re-use of the medium, were determined. Total cooking, drip, volatile, and volume losses were recorded. Six taste panel members scored roasts representing each cooking method for aroma, flavor, color, texture, juiciness, softness, friability, residual connective tissue, and general tenderness. Color reflectance, juiciness, and tenderness were objectively measured.

Oven roasts required approximately twice as long to reach the desired end cooking temperature than roasts cooked in fat. The rate of heat penetration was slower in oven-roasted samples than in roasts cooked by deep fat immersion.

Heat penetration curves at all sample depths measured were similar in shape for roasts cooked in fat. Rate of heat penetration for all depths increased rapidly from the initial temperature to a maximum point at internal temperatures of 40 to 50°C. After these temperatures were attained, the penetration rate gradually decreased throughout the remainder of the cooking period. There was more variation in the rate of heat penetration in oven roasts than in samples cooked in fat. At the 1/4-inch depth the rate of penetration decreased steadily as the temperature of the roasts increased. Heat penetration rate for the 3/4-inch depth generally increased to internal temperatures of 40 to 50°C and then decreased gradually as the degree of doneness progressed. Rate of heat penetration for the radius increased rapidly to an internal temperature of 40°C and then decreased sharply during the remainder of the cooking period.

For all roasts cooked in air or in fat, heat penetration rate decreased as roasts approached the rare stage. However, for each sample depth measured the rise in internal temperature for meat cooked in 115°C fat was faster than for roasts cooked in 149°C air. As the degree of doneness progressed the rate of heat penetration and the time required for the center of roasts to reach 80°C appeared to be affected by the degree of protein denaturation and evaporation. Heat penetration rate appeared to decrease as the thickness of coagulated protein increased.

Determinations of pH indicated that cooked roasts were slightly more alkaline than raw roasts. However, changes in pH brought about by cooking were not significant for method. Smoke point determinations showed that changes in the smoking temperature of the hydrogenated fat, resulting from re-use of the cooking medium, were slight.

Analyses of variance revealed highly significant differences in cooking and volume losses attributable to method of cookery. Total cooking and volatile losses were significantly smaller for oven roasts than for roasts cooked in fat. Drip losses were significantly greater for oven roasts than for roasts cooked in deep fat. Correlation between total cooking loss and juiciness showed the expected inverse relationship, significant at the 1% level. Volume losses for roasts cooked in deep fat were significantly greater than comparable losses for oven-roasted samples. In addition, roasts cooked in deep fat showed greater volume loss than weight loss.

Except for juiciness, mean palatability scores for oven-roasted samples and for those cooked in deep fat were very similar. Average aroma scores were identical for the two methods. Judges scores indicated only slight preference for the flavor and texture of oven-roasted samples. Scores for color, softness, friability, residual tissue, and general tenderness favored the samples cooked in deep fat. Statistical analysis revealed highly significant differences in juiciness scores attributable to cooking method. Juiciness score averages for samples cooked by deep fat immersion were significantly lower than those for oven-roasted samples.

Aroma scored higher than any other palatability factor for both methods of cooking. Flavor was judged good, but faint. Scores for color and texture averaged fair to good. Average scores of neither dry nor juicy, and neither hard nor soft, were given for juiciness and softness, respectively. Friability scores averaged moderately friable, indicative of a small amount of firm to soft connective tissue. All samples from both methods were described as slightly tough.

Positive correlations, significant at the 1% level, were found between softness/tenderness, friability/tenderness, and softness/friability. The coefficient between residual tissue and tenderness nearly approached significance at the 1% probability level. Positive correlations, significant at the 5% level, were obtained for residual tissue/friability and residual tissue/softness.

Objective measurements of color, juiciness, and tenderness substantiate subjective evaluation. Spectral curves for raw and cooked samples were similar for both cooking treatments. Raw and cooked samples appear to have a characteristic reflectance spectra minima. Statistical analysis indicated no significant difference in the change in color reflectance between raw and cooked samples due to cooking method. Significantly greater press fluid yields were obtained from roasts cooked in 149°C air than from roasts cooked in 115°C fat. There was a positive correlation, significant at the 1% level, between juiciness scores and press fluid yields. Average shear force readings were slightly lower for roasts cooked in fat than for oven roasts. Correlation coefficients between shear readings and general tenderness, softness, friability, and residual tissue were not significant.

From this investigation it appears that cooking time, cooking losses, changes in linear measurements, and palatability of roasts from semimembranosus muscles of beef round depend upon the rate of heat transfer from the cooking medium to the sample when contact heat remains constant and sample size is standardized. Within the limits of this study the following conclusions appear to be relevant:

1. The transfer of heat from the cooking medium to the sample is more rapid in fat than in air. To reach an internal temperature of 80°C roasts cooked in 115°C hydrogenated fat required approximately half the time required by roasts cooked in 149°C air. The heat penetration rate during cooking varied more for oven roasts than for roasts cooked in deep fat.

2. The rate of heat penetration in cooked tissue is slower than in raw tissue. Irrespective of cooking method, minutes per degree Centigrade rise increased as roasts approached the rare stage. Protein coagulation and cooking losses increased as samples progressed from the rare stage to the well-done stage. As the degree of doneness increased, rate of heat penetration decreased markedly.

3. Method of cooking influences cooking losses. Total, volatile, and volume losses were significantly less for oven roasts than for roasts cooked by deep fat immersion. This may be due, in part, to the faster and more efficient transfer of heat provided by the fat medium. Even though significantly greater amounts of drip were obtained from conventionally roasted samples, these roasts were significantly more juicy than samples cooked in deep fat.

4. Semimembranosus samples cooked in fat compared favorably with similar samples cooked in air for all palatability characteristics studied except juiciness. Results obtained seem to indicate that the components of tenderness--softness, friability, and residual tissue--may be distinguished subjectively.

5. The internal temperature rise during cooling is greater for roasts cooked in deep fat than for oven-roasted samples. From the data, it appears that the internal temperatures of tissues 1/4-inch and 3/4-inch from the surface of the sample are higher than for comparable tissues in oven-roasted samples.

6. Hydrogenated fats with relatively high smoking temperatures may be used successfully as a medium for roasting beef at moderate temperatures.

7. Method of cooking did not appear to influence changes in color reflectance brought about by cooking.

Research concerning the effect of different methods of dry heat cookery on rate of heat penetration, cooking losses, and palatability of beef round muscles is extremely limited. Additional work needs to be done to determine the rate and extent of weight loss during cooking, the thermal conductivity of beef muscles, the rate of heat transfer of different cooking media, and the time required for cooking to different degrees of doneness in various cooking media.

Results of this study suggest that cooking by deep fat immersion might be acceptable if a method of procedure could be established whereby palatability and rate of heat penetration could be maintained and cooking losses reduced. It is conceivable that losses more comparable to those of oven roasts might be obtained if deep fat roasts were cooked at slightly lower temperatures and to a lower internal temperature. Modification in method, in which a higher fat temperature is maintained until protein coagulation begins, followed by a lower fat temperature for the remainder of the cooking period, may result in increased palatability with lower cooking losses.

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APPENDIX

Table 14. Weight of rounds, muscle weight, maximum linear measurements of muscles, and trimmed sample weight.

Left Round	Weight Rump on (lb.)	Weight Muscle (gm.)	Maximum Linear Measurements (in.) Length	Width	Depth	Trimmed Sample (gm.)
1	79.6	3341	12.75	6.50	3.63	1534
2	84.5	3828	13.75	7.13	3.63	1540
3	76.0	3380	12.50	6.88	3.63	1461
4	70.2	3042	12.83	6.75	3.38	1330
5	72.4	2907	11.33	6.88	3.88	1285
6	79.0	3421	14.00	7.25	3.88	1552
Right Round						
1	77.0	3373	12.50	7.13	3.63	1392
2	76.2	3752	12.75	6.75	3.88	1560
3	76.1	3315	13.38	7.13	4.00	1356
4	67.2	3066	12.75	7.38	3.25	1213
5	70.8	2890	11.75	6.75	3.50	1526
6	75.0	3394	13.75	6.63	3.88	1543

PROCEDURE FOR DETERMINING TEMPERATURE TO EQUATE CONTACT HEAT OF FAT AND OF AIR

__Conduction__ __Heating__ __Equation__:

$$q = Ah(t_1 - t_2)T$$

Where:

q = heat input (Btu)

A = surface area (square feet)

h = averate heat transfer coefficient*

t_1 = heating medium temperature (°F)

t_2 = surface temperature (°F)

T = time (hours)

*Units of $h = \dfrac{\text{Btu}}{(\text{sq. ft.})(°\text{F})(\text{hr.})}$

__Assumptions__:

a) constant surface area.

b) constant heat input.

c) surface temperature = 212°F.

Calculations for this investigation based on material presented in Giedt (34), Jakob (48), Marks (56), and Miner and Dalton (60).

Average heat coefficients:

h_{air} = 1.0 when the $t_{1\ air}$ is between 250 and 350°F.

h_{fat} = 6.7 when the $t_{1\ fat}$ is between 200 and 300°F.

For this study, average cooking times in air and in fat established by preliminary trials were:

$$T_{air} = 2.60 \text{ hours}$$

$$T_{fat} = .98 \text{ hours}$$

If $t_{1\ air}$ is 300°F, then $t_{1\ fat}$ may be determined as follows:

$$h_{air}\,(t_{1\ air} - t_2)T_{air} = h_{fat}\,(T_{1\ fat} - t_2)T_{fat}$$

$$1(300\text{-}212)2.60 = 6.7\,(t_{1\ fat} - 212).98$$

$$\frac{(88)(2.60)}{(6.7)(.98)} = t_{1\ fat} - 212$$

$$34.85 = t_{1\ fat} - 212$$

$$t_{1\ fat} = 212 + 34.85$$

$$t_{1\ fat} = 246.85°F\ (247°F = 119\ C)$$

Since these calculations were based on preliminary trials in which cooking time varied greatly, it was decided to use the next lowest temperature on the fryer thermostat. This was 115°C. In addition, products from preliminary trials cooked at 115°C most nearly resembled the conventionally oven-roasted samples both in appearance and palatability.

Meat Score Card

Sample No. ____________
Identification ____________

Judge ____________
Date ____________

	7	6	5	4	3	2	1
Aroma	Rich, meaty	Very meaty	Good, full	Good, faint	Fair	Fair, faint	Lacking or Unpleasant
Color	Very desirable	Desirable	Good, typical	Fair to good	Fair	Washed-out Dark Discolored	Poor
Texture	Very fine, regular	Fine grain	Good	Fair to good	Slightly coarse	Coarse, stringy	Very coarse, stringy
Flavor (lean)	Rich, meaty	Very meaty	Good, full	Good, faint	Fair	Fair, faint	Lacking or Unpleasant
Juiciness	Extremely juicy	Very juicy	Juicy	Neither juicy nor dry	Dry	Very dry	Too dry to swallow easily
Softness	Extremely soft	Very soft	Soft	Neither hard nor soft	Hard	Very hard	Too hard to chew easily
Friability	Extremely friable	Very friable	Friable	Moderately friable	Slightly friable	Very slightly friable	Not friable
Amt. and state of residual connective tissue	No C.T. felt	Tiny amount of soft C.T.	Small amount of soft C.T.	Small amount of firm C.T.	Medium amount of firm C.T.	Medium amount of hard C.T.	Large amount of hard C.T.
Tenderness impression + No. of chews for complete mastication	Extremely tender	Very tender	Tender	Slightly tough	Tough	Very tough	Extremely tough

Table 15. Changes in the rate of heat penetration for five replications, for three sample depths for two cooking methods.

Deep Fat Method Samples (Min./°C rise)

1/4-inch Depth

Temperature °C	Replications					Mean
Initial - 20	.65	1.38	1.00	.82	.75	.92
20 - 30	.45	1.38	.60	.45	.50	.67
30 - 40	.35	.85	.65	.35	.40	.52
40 - 50	.55	.80	.75	.35	.30	.55
50 - 60	.65	.75	.70	.35	.55	.60
60 - 70	.70	1.10	.95	.55	.65	.79
70 - 80	1.20	1.00	.95	.65	.85	.93

3/4-inch Depth

Temperature °C	Replications					Mean
Initial - 20	.96	1.39	1.54	1.30	1.60	1.36
20 - 30	.60	.95	.65	.60	.70	.70
30 - 40	.75	.70	.65	.50	.60	.64
40 - 50	.60	.70	.60	.55	.60	.61
50 - 60	.70	.70	.70	.65	.75	.70
60 - 70	1.00	.85	.75	.90	.85	.87
70 - 80	1.55	1.00	1.15	1.20	1.05	1.19

1 1/2-inch Depth (radius)

Temperature °C	Replications					Mean
Initial - 20	1.50	2.07	1.57	1.71	1.94	1.76
20 - 30	.80	.70	.50	.70	.80	.70
30 - 40	.65	.70	.50	.60	.65	.62
40 - 50	.75	.75	.60	.70	.70	.70
50 - 60	.85	.85	.75	.70	.80	.79
60 - 70	1.15	.90	.85	.85	.95	.94
70 - 80	1.50	1.00	1.20	.95	1.00	1.13

Table 15 (Contd.)

1/4-inch Depth		Conventional Method Samples (Min./°C rise)				
Replications					Mean	Temperature °C
.68	.79	.70	.72	.65	.71	Initial - 20
1.00	.95	1.20	.60	1.40	1.03	20 - 30
1.14	1.25	1.80	.95	1.60	1.35	30 - 40
1.65	1.60	1.70	1.10	1.35	1.48	40 - 50
1.85	1.80	1.45	1.20	1.70	1.60	50 - 60
1.95	1.80	2.70	1.20	2.10	1.95	60 - 70
3.75	2.80	2.50	2.10	2.55	2.74	70 - 80
3/4-inch Depth						
1.50	1.08	1.31	1.15	1.79	1.37	Initial - 20
1.30	1.20	1.30	.90	1.40	1.22	20 - 30
1.45	1.40	1.60	1.10	1.25	1.36	30 - 40
1.40	1.40	1.15	1.20	1.30	1.29	40 - 50
1.75	1.90	1.25	1.35	1.45	1.54	50 - 60
2.90	2.15	1.75	1.75	1.50	2.10	60 - 70
2.90	2.50	2.45	2.50	2.15	2.50	70 - 80
1 1/2-inch Depth (radius)						
1.93	2.11	2.07	1.64	2.21	1.99	Initial - 20
1.30	1.30	1.50	1.30	1.35	1.35	20 - 30
1.20	1.30	1.55	1.25	1.35	1.33	30 - 40
1.55	1.45	1.60	1.35	1.50	1.49	40 - 50
1.75	1.60	2.05	1.50	1.80	1.74	50 - 60
2.25	1.80	2.45	2.45	2.15	2.22	60 - 70
2.95	2.80	2.95	2.85	2.95	2.90	70 - 80

Table 16. Determinations of pH for raw and cooked samples and the change in pH for six roasts for two methods of cookery.

Method of Cooking	pH Readings		
	Raw Samples	Cooked Samples	Change
Deep Fat	5.6[1]	5.8	0.2
	5.4	5.8	0.4
	5.5	5.8	0.3
	5.6	5.8	0.2
	5.7	5.7	0.0
	5.6	5.9	0.3
Conventional	5.6	5.9	0.3
	5.6	5.8	0.2
	5.5	5.8	0.3
	5.7	5.7	0.0
	5.6	5.6	0.0
	5.6	5.8	0.2

[1]Based on 2 readings.

Table 17. Cooking weight losses for six roasts for two methods of cookery.

Method of Cooking	Raw Weight (gm.)	Cooked Weight (gm.)	Total Loss (gm.)	Total Loss %	Drip Loss %	Volatile Loss %
Deep Fat	1308	815	493	37.69	1.32	36.37
	1250	787	463	37.04	1.76	35.28
	1188	705	483	40.66	.81	39.85
	1086	664	422	38.86	.71	38.15
	987	612	375	37.99	1.36	36.63
	1268	796	472	37.22	1.44	35.79
Average	1181	730	451	38.24	1.23	37.01
Conventional	1089	727	362	33.24	1.74	31.50
	1056	697	359	34.00	2.37	31.63
	1264	827	437	34.57	1.27	33.31
	1212	818	394	32.51	2.56	29.95
	1248	830	418	33.49	2.24	31.25
	1279	883	396	30.96	2.03	28.93
Average	1199	797	402	33.13	2.04	31.10

Table 18. Volume loss for six roasts for two methods of cookery.

Method of Cooking	Volume in Milliliters Raw Sample	Cooked Sample	Change	Volume Loss %
Deep Fat	1175	650	525	44.68
	1230	710	520	42.28
	995	535	460	46.23
	998	470	528	52.91
	970	510	460	47.42
	1085	695	390	35.95
Average	1076	595	481	44.91
Conventional	965	620	345	35.75
	860	585	275	31.98
	1070	745	325	30.37
	1000	745	255	25.50
	1055	695	360	34.12
	1135	770	365	32.16
Average	1014	693	321	31.65

Table 19. Average palatability scores of six judges for six replications for two cooking methods.

Method of Cooking	Aroma	Flavor	Color	Texture	Juiciness	Softness	Friability	Residual Tissue	General Tenderness
Deep Fat	5.0	4.8	4.7	4.5	3.2	5.0	4.7	4.8	5.2
	4.8	4.5	4.8	4.2	3.8	4.3	3.3	4.5	4.3
	5.2	4.2	5.2	4.3	3.0	3.8	3.7	4.7	4.2
	5.2	4.5	4.8	4.0	3.7	4.8	4.0	5.5	4.8
	4.8	4.7	4.8	4.3	4.3	4.0	3.2	4.7	4.5
	5.0	4.5	4.8	4.0	4.0	4.5	3.5	4.7	4.2
Grand Average	5.0	4.5	4.9	4.2	3.7	4.4	3.7	4.8	4.5
Conventional	5.2	4.8	5.0	4.0	4.5	4.2	3.0	4.3	3.7
	4.7	4.5	4.8	4.8	4.5	3.8	3.2	4.3	3.7
	5.2	5.0	4.2	4.6	4.0	4.5	4.3	4.8	4.7
	5.0	4.5	4.2	4.3	4.5	4.3	3.7	4.8	4.8
	5.2	4.3	4.7	5.0	4.3	4.7	3.8	5.0	4.5
	4.7	4.8	4.0	4.5	4.3	4.3	3.7	4.8	4.5
Grand Average	5.0	4.7	4.5	4.5	4.4	4.3	3.6	4.7	4.3

Table 20. Per cent color reflectance. Average of six replications for two methods of cookery.

Wave-length	415	445	475	505	535	545	565	595	625	655	685
Deep Fat											
Raw	15.7[1]	18.3	22.5	22.3	19.0	19.0	19.4	24.4	30.8	33.8	39.5
Cooked	19.8	24.5	29.0	28.0	26.8	26.6	27.9	30.7	32.0	33.0	38.7
Change	4.1	6.2	6.5	5.7	7.8	7.6	8.5	6.3	1.2	-.8	-.8
Conventional											
Raw	15.6	18.1	22.5	21.7	19.4	18.8	19.3	23.8	30.7	33.2	38.1
Cooked	20.1	25.3	30.0	29.7	27.7	27.6	29.0	31.6	33.4	34.7	39.0
Change	4.5	7.2	7.5	8.0	8.3	8.8	9.7	7.8	2.7	1.5	.9

[1] Based on 2 readings.

Table 21. Average press fluid yields and shear force readings of cooked samples for six replications for two cooking methods.

Method of Cooking	Press Fluid (%)	Shear Force (lb.)
Deep Fat	36.96[1]	19.30[2]
	34.09	19.45
	34.21	17.85
	36.52	17.95
	35.78	19.25
	35.78	19.55
Grand Average	35.56	18.89
Conventional	40.00	18.65
	38.64	19.40
	39.50	19.40
	38.94	19.35
	38.98	19.35
	36.28	20.01
Grand Average	38.72	19.36

[1]Based on 2 determinations.

[2]Based on 5 determinations.

EFFECT OF TWO METHODS OF DRY HEAT COOKERY

ON PALATABILITY AND COOKING LOSSES OF SEMIMEMBRANOSUS MUSCLE

OF BEEF ROUND

By

Zenovia Jean Lukianchuk

AN ABSTRACT

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ABSTRACT

In this study, the effects of conventional oven-roasting and of cooking by deep fat immersion on cooking losses, rate of cooking, and palatability of semimenbranosus muscles from six pairs of U.S.D.A. Choice steer beef rounds were compared.

The temperature of the cooking mediums was equated so that the contact heat was considered comparable for roasts cooked in air or in fat. Experimental samples, standardized with respect to size and shape, averaged 1200 grams, with linear measurements of 6 x 4 x 3 inches for length, width, and depth, respectively. Prior to cooking, each sample was defrosted and potentiometer leads were positioned at depths of 1/4-, 3/4-, and 1 1/2-inches from the surface. Roasts were individually cooked at 149°C in air or at 115°C in fat until all potentiometer leads had reached a minimum internal temperature of 80°C.

From the data of this investigation it appeared that cooking time, cooking losses, changes in linear measurements, and palatability of roasts are affected by the rate of heat transfer from the cooking medium to the sample when sample size, contact heat, and degree of doneness are controlled.

Transfer of heat was more rapid in fat than in air. To reach an internal temperature of 80°C, roasts cooked in 115°C hydrogenated fat required approximately half the time required by roasts cooked in 149°C air. Heat penetration rate during cooking varied more for oven roasts than for roasts cooked in hot fat.

Rate of heat penetration in cooked tissue was slower than in raw tissue. Irrespective of cooking method, minutes per degree Centigrade rise in internal temperature increased as roasts approached the rare stage. As degree of doneness increased, cooking losses increased and rate of heat penetration decreased markedly.

The internal temperature rise after removal from the cooking medium was greater for roasts cooked in deep fat than for oven-roasted samples. In addition, inner temperatures of tissues 1/4- and 3/4-inch from the surface of the samples were higher than for comparable tissues in oven-roasted samples.

Total, volatile, and volume losses were less for oven roasts than for roasts cooked by deep fat immersion. Although greater amounts of drip were obtained from conventionally roasted samples, these roasts were significantly more juicy than samples cooked in deep fat.

Changes in color brought about by cooking, as measured by per cent color reflectance, did not appear to be affected by method.

Semimembranosus samples cooked in fat compared favorably with similar roasts cooked in air for all palatability characteristics studied except juiciness. Results obtained indicated that components of tenderness--softness, friability, and residual tissue--may be distinguished.

The findings of this limited study emphasize that rate of heat transfer from the cooking medium to the sample plays a significant role in the determination of cooking time, cooking losses, and palatability of roasts of predetermined size and shape. Additional investigation of the interaction of factors, such as contact heat, rate of heat transfer, thermal conductivity of beef, sample size and shape, and degree of doneness needs to be made before procedures for cooking beef roasts by deep fat immersion can be established.