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EFFECTS OF END POINT AND OVEN TEMPERATURES ON BEEF ROASTS
COOKED IN OVEN FILM AND OPEN PANS

by

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INTRODUCTION

Oven film cooking bags are offered to the homemaker as a new method of meat cookery. Film bags are marketed under several brand names, and one manufacturer suggests that lower cost, less tender cuts of meat ideally are suited to cooking in film. This is in agreement with the usual recommendation that moist heat (braising or pot roasting) be used to cook less tender cuts to soften collagenous connective tissue. Manufacturers sometimes imply in advertising that their product will produce a juicier, more flavorful roast in a shorter time than is otherwise possible.

In general, data have indicated that tender cuts require longer cooking time, but have less weight and nutritive loss, and are more palatable when cooked by dry heat (roasting, broiling, deep fat frying) than when cooked by moist heat. Schock et al. (1970) studied the effects of two dry heat treatments (oven roasting, deep fat frying) and two moist heat treatments (oven braising, pressure braising) on beef semimembranosus muscle from top round cooked to an internal temperature of 70°C. They found no significant differences attributable to heat treatment for flavor, tenderness, and overall acceptability. Total moisture and press fluid yield were higher ($P < 0.05$) for oven roasted pieces, whereas, the rate heat penetrated was slower ($P < 0.05$) and the cooking time was longer ($F < 0.05$) for oven roasting than for any of the other treatments.

Reid and Harrison (1971) reported that selected histological characteristics of the beef cooked by Schock et al. (1970) did not vary significantly among heat treatments. They suggested that variations among similar data appearing in the literature may be attributable to variations in method of

measurement; age, maturity, or grade of animals; or treatments other than heat treatments.

Ferger et al. (1972) studied effects of: (1) roasting and cooking in oven film on boned and rolled leg of lamb roasts cooked from the frozen state at 163°C to an internal temperature of 75°C, and (2) roasting and cooking in oven film on beef rib roasts cooked from the frozen state at 149°, 163°, or 177°C to an internal temperature of 60°C. They concluded that (1) there is little difference between dry and moist heat in cooking time, percentage total cooking losses, flavor, juiciness, and tenderness of meat cooked from the frozen state to the same internal temperature, (2) dry heat produces meat that appears less well-done than meat cooked by moist heat to the same internal temperature, and (3) time for cooking beef rib roasts from the frozen state by dry or moist heat is not shortened significantly by increasing the oven temperature above that usually recommended. Both cuts of meat used in the study by Ferger et al. (1972) are tender cuts.

No data were found for cooking a less tender cut of meat from the frozen state by roasting and cooking in oven film. Manufacturers of oven film recommend oven temperatures of 350° to 400°F (177° to 205°C). This study was designed to investigate effects on beef top round of roasting and cooking in oven film at two oven temperatures (177° and 205°C) and to three end point (internal) temperatures (60°, 70°, 80°C).

REVIEW OF LITERATURE

Effect of Type of Heat on Selected Characteristics of Beef

Methods of meat cookery, based on the condition of the atmosphere surrounding the meat, traditionally are classified as dry or moist heat methods. Roasting in an open pan is a dry heat method in which the transfer of heat is from the hot air in the oven to the external surface of the meat, and from the surface to the center of the cut of meat. Cooking in a covered pan, aluminum foil, or an oven film cooking bag creates a moist atmosphere surrounding the meat. Heat is transferred more rapidly to the surface of the meat when it is cooked by moist heat rather than by dry heat; thus, with moist heat the meat is heated throughout more rapidly (Paul, 1972, p. 412-413).

Fibers and connective tissue. Moist heat cooking methods have been recommended for cuts of meat containing moderate to large quantities of connective tissue. Slow cooking in a moist atmosphere was considered necessary to soften collagenous connective tissue by partial hydrolysis of collagen, and thus tenderize the meat. Dry heat methods have been recommended for cuts of meat containing relatively small quantities of connective tissue. Effects of cooking on tenderness of such cuts was considered to be related more to the coagulation of muscle fiber proteins than to changes in connective tissue.

Irvin and Cover (1959) measured the average collagen nitrogen content of raw and broiled steaks from the longissimus dorsi and biceps femoris muscles of 26 animals. They found that the biceps femoris contained more ($P < 0.01$) collagen nitrogen than the longissimus dorsi. The collagen

nitrogen content of raw meat was greater ($P < 0.001$) than that of cooked meat for both muscles. The collagen nitrogen content of both muscles was reduced by approximately 25% by broiling to 61°C . They pointed out that the reduction in collagen nitrogen occurred with a mild heat treatment, and they believed this indicated that some of the collagen was affected by heat more readily than had been believed previously. Moisture in the muscles probably was sufficient to create an atmosphere conducive to the hydrolysis of collagen. The percentage loss of collagen nitrogen resulting from the dry heat treatment was approximately the same for the two muscles. Comparisons made between collagen nitrogen content and judges' scores for tenderness of connective tissue (0 = residue very hard, 10 = no connective tissue felt) showed that the collagen nitrogen content was higher ($P < 0.001$) and the scores for connective tissue were lower for biceps femoris than longissimus dorsi. Irvin and Cover (1959) suggested a relationship between collagen as a chemical entity and the "ability" of the judges to score the tenderness or toughness of connective tissue.

Reid and Harrison (1971) investigated the effects of deep-fat frying, oven roasting, oven braising, and pressure braising to 70°C on the histological characteristics of beef semimembranosus muscle. They found that heating by any of the methods decreased fiber width about 10%, with the difference between the effects of dry heat and moist heat being only 0.25%. The relative proportion of straight and wavy connective tissue was not affected significantly by heat treatment, but there was a larger ($P < 0.05$) proportion of granular connective tissue in deep-fat fried, pressure braised, and oven braised meat than in oven roasted meat.

Cooking time. Moist heat and dry heat cooking methods differ in the rate at which heat energy is supplied to the external surface and in the temperature to which the surface of the meat is exposed (Paul, 1972, p. 413).

An early study dealing with cooking time required for various cooking methods concluded that there was no difference in the total cooking time for standing beef rib roasts cooked in open and covered pans (Morgan and Nelson, 1926).

Cover et al. (1957) found that total cooking time was less ($P < 0.001$) for both longissimus dorsi and biceps femoris steaks when braised (moist heat) than when broiled (dry heat). In an earlier study by Cover (1941), roasts were cooked in uncovered pans in a ventilated oven and submerged in a water bath. The cooking temperature was 90°C in both instances. Meat cooked in water required less than three hours total cooking time, whereas that in the oven required more than 23 hours.

Cover and Smith (1956) reported that oven roasted standing rib roasts required three times longer to cook than those that were pot roasted.

U. S. Good and U. S. Standard "shoulder of beef" roasts were cooked by dry heat in an open pan and by moist heat in heavy aluminum foil by Hood (1960). Cooking time in minutes per pound was longer ($P < 0.05$) for cooking by dry heat. Similarly, Hood et al. (1955) found that cooking portions of semimembranosus and biceps femoris muscles by dry heat required more time than cooking by moist heat.

Data from those studies indicate that the higher rate of transfer of heat energy to the surface of the meat and the higher temperature to which

the surface of the meat is exposed result in more rapid cooking by moist than by dry heat methods.

Schock et al. (1970) reported that roasts of beef semimembranosus muscle reached 70°C internal temperature most quickly when pressure braised (10 psig), followed by deep fat frying, oven braising, and oven roasting, in that order. Slightly less time was required for oven braising than oven roasting, but the difference was not significant.

Ferger et al. (1972) cooked boned and rolled legs of lamb and boned beef rib roasts by dry heat in open pans and by moist heat in oven film. Unexpectedly, less time ($P < 0.01$) was required to cook leg of lamb roasts by dry heat than by moist heat. Although less time was required for cooking beef rib roasts by moist heat than by dry heat, the difference was not significant.

Cooking losses. Cooking losses for any method of cooking generally increase with increasing cooking time. This relationship of cooking time and cooking losses suggests that losses should be greater for meat cooked by dry heat than for meat cooked by moist heat. This assumption held for standing rib roasts that were pot roasted or oven roasted by Cover and Smith (1956). The oven roasted meat required longer cooking time and lost slightly more weight during cooking. However, broiled loin steaks required shorter cooking time, but lost more weight during cooking than braised loin steaks.

In general, other authors have reported longer cooking time and less cooking loss with dry heat than with moist heat. Nielsen and Hall (1965) reported that braised blade roasts had greater total cooking losses than

roasted blade or rump roasts. Cooking times were not reported for the braised blade roasts.

Hay et al. (1953) studied the effects of a meat tenderizer on round steaks braised or broiled to 80° or 65.6°C, respectively. The cooking times for those treatments were similar, but the total cooking losses were greater for braised steaks than for broiled steaks. This was true for both untreated steaks and those that were treated with tenderizer.

Although oven roasting required the longest cooking time, beef top round roasts (SM muscle) lost less ($P < 0.05$) weight when cooked by oven roasting than by oven braising, pressure braising, or deep fat frying (Schock et al., 1970).

Ferger et al. (1972) reported that percentages of total and dripping losses, based on the weight of frozen leg of lamb roasts, were not significantly different between dry and moist heat treatments, despite the shorter ($P < 0.01$) cooking time reported for dry heat. Total cooking losses from boneless beef rib roasts cooked from the frozen state by Ferger et al. (1972) were not affected significantly by type of heat.

Palatability. Dawson et al. (1959) summarized data for corresponding cuts of U. S. Good and U. S. Commercial grade beef round cooked by dry and moist heat methods to the same internal temperature. Differences attributable to type of heat, when found, in scores for tenderness and flavor were generally in favor of dry heat methods of cooking. However, the results varied slightly among the experiment stations conducting the work. It was concluded that roasting or broiling cuts of U. S. Commercial or U. S. Good grade beef at 149° or 177°C to an internal temperature of 80° or 85°C could be expected to give meat as tender and flavorful as braising, and the meat

probably would be just as juicy. When different end point temperatures of cooking were compared, round steaks roasted to 75.6°C were significantly more palatable than those oven braised to 80°C.

Loin and bottom round steaks cooked by Cover et al. (1957) were juicier ($P < 0.001$) when broiled to 80°C internal temperature than when braised to 100°C. Juiciness probably was affected by an interaction between types of heat (methods of cooking) and internal temperature, but the effect of each factor per se was not demonstrated. In commenting on the large difference in juiciness scores in comparison to the small difference in cooking losses, the authors suggested that water relationships inside the meat apparently undergo changes that differ quantitatively as a result of the two conditions of cooking.

Shear values for meat cooked by Cover et al. (1957) indicated that longissimus dorsi steaks were most tender when broiled to the rare stage (61°C) and biceps femoris steaks were most tender when braised well-done (100°C + 25 min).

Morgan and Nelson (1926) compared the effects of roasting and braising on standing beef rib roasts. There was no difference in the appearance or the flavor of the meat cooked by the two methods, although the outer fat covering of roasts cooked in open pans was sometimes slightly charred.

Cover (1941) reported that when roasts were cooked at 90°C in an open pan or submerged in a 90°C water bath, tenderness evaluated by the paired-eating method showed 100% of the judgments in favor of the oven roasts. When described by five weighted adjectives, oven roasts were tender, whereas those cooked in water frequently were tough.

Nielsen and Hall (1965) concluded that U. S. Choice grade blade roasts can be successfully roasted at 107° or 163°C. Blades roasted at both temperatures were considered juicier ($P < 0.01$) by a taste panel than braised blades. There were no differences among the roasts for tenderness, flavor, or general acceptability.

Griswold (1955) found that roasting at 121°C is a good method for cooking beef round except for the dry surface appearance that results from the long cooking time required.

Hood (1960) cooked roasts from the triceps brachii of U. S. Good and U. S. Standard carcasses by dry heat in an open pan, and by moist heat in heavy aluminum foil. In both grades, dry heat produced more tender roasts than did moist heat as evaluated by shear values.

Schock et al. (1970) reported that no differences attributable to heat treatment were found for flavor, tenderness, or overall acceptability of beef semimembranosus muscle cooked to 70°C by oven roasting, oven braising, pressure braising, or deep fat frying. Oven roasted pieces were juicier than those that were oven braised, with the difference approaching significance at the 5% level.

Deethardt and Tuma (1971) cooked pork loin roasts by four methods, including one dry heat treatment, one moist heat treatment (covered with heavy aluminum foil), and two combinations of dry and moist heat (open pan to 52°C and then covered, and covered to 52°C and then open pan). Mean panel scores for texture favored the open pan method with the completely covered method scoring lowest. Mean juiciness scores indicated that pork cooked in open pans was juicier ($P < 0.01$) than that cooked completely covered, and pork cooked by both methods was juicier ($P < 0.01$) than that cooked by the

combination treatments. Tenderness was not affected significantly by cooking method. The authors concluded that the panel members indicated no obvious overall preference for any one cooking method.

Ferger et al. (1972) found that lamb roasts were juicier ($P < 0.05$) when cooked by dry than by moist heat. Other palatability characteristics of the lamb roasts were not significantly affected by heat treatments. Juiciness and tenderness scores for beef rib roasts, also cooked by Ferger et al. (1972), were not affected significantly by type of heat. Beef roasts cooked by dry heat at 163°C were scored higher for flavor and overall acceptability than roasts cooked by moist heat.

Degree of doneness. Schock et al. (1970) reported that mean scores for apparent degree of doneness of beef semimembranosus muscle were lower ($P < 0.05$) for meat cooked by oven roasting than any of the other treatments, indicating that oven roasted meat appeared less well-done.

Ferger et al. (1972) found that at an internal temperature of 75°C in leg of lamb roasts and 60°C in beef rib roasts the meat appeared less well-done when cooked by dry heat than by moist heat.

Effect of Rate of Heat Penetration on Selected Characteristics of Beef

Fibers and connective tissue. Cover (1943) studied the effects of low rates of heat penetration on the tenderness of beef roasts. Standing rib and arm bone chuck roasts were cooked well-done, and bottom round roasts were cooked both rare and well-done at oven temperatures of 80° and 125°C . Beef appeared well-done when cooked to 70°C in the 80°C oven, and to 63°C in the 125°C oven. In well-done roasts cooked at 80°C the connective tissue was completely changed from its hard, tough state to a moist, viscous mass

without resistance to the knife or teeth. Paired roasts cooked at 125°C contained some visible connective tissue that offered resistance to chewing. The muscle fibers in well-done roasts which required 40 hours to lose their pink color were so tender that they were often-described as "mealy".

Paul et al. (1952) found that the slow heat penetration during roasting of bottom round roasts to 63°C induced the development of rigor in roasts cooked immediately after slaughter. As observed by histological investigation the rapid heat penetration during deep fat frying of bottom round steaks to 63°C coagulated the muscle substance before rigor could develop.

Cooking time. Cooking time for beef roasts cooked by Cover (1943) was from 3 to 5 times longer at an oven temperature of 80°C than at 125°C. Similarly, Bramblett and Vail (1964) reported that beef adductor, biceps femoris, gracilis, semimembranosus, and semitendinosus muscles cooked at 88.3°C required 2 to 4 times longer to cook than did the same muscles cooked at 93.3°C. Cover (1941) also reported that as a result of the poorer conduction of heat by air than by water, beef roasts cooked in air required nearly 8 times longer to reach the same degree of doneness as those cooked in water. Likewise, the rate of heat penetration was more rapid for beef roasts from 7 muscles cooked in deep fat at 100° and 110°C than for similar roasts cooked in a 149°C oven (Visser et al., 1960).

Weir et al. (1963) produced variation in the rate at which heat penetrated pork loin muscle by varying the oven temperature. Pork loin roasts cooked at oven temperatures of 149°, 163°, 190.6°, and 205°C were compared to paired roasts cooked at 177°C. In each comparison, heat penetrated the muscle more rapidly at the higher oven temperature. Total cooking time was

reduced ($P < 0.01$ and $P < 0.05$, respectively) by increasing the oven temperature from 177° to 190.6° and 205°C .

Cooking losses. Weir et al. (1963) recorded the yield of cooked meat and percentage dripping loss and evaporation loss for roasts cooked at oven temperatures ranging from 149° to 205°C . The percentage yield of cooked meat was less ($P < 0.05$ and $P < 0.01$, respectively) when roasts were cooked at 190.6° and 205°C than at 177°C . Percentage dripping loss was similar at all oven temperatures, but percentage evaporation loss was higher for the higher oven temperature when roasts cooked at 177°C were compared with those cooked at 149° , 190.6° , and 205°C .

The percentage total cooking losses was less ($P < 0.01$) for beef round roasts cooked slowly in a 63°C oven than for those cooked more rapidly at 68°C (Bramblett et al., 1959). Beef rib, chuck, and round roasts cooked to 70° and 80°C at oven temperatures of 80° and 125°C , respectively, differed little in percentage total cooking losses, and the same was true for round roasts cooked to $58-59^{\circ}$ and 63°C at the same oven temperatures, despite substantially longer cooking times at the lower oven temperatures (Cover, 1943).

Clark and Van Duyne (1949) reported that total cooking losses from beef top round roasts were greater when the meat was cooked to an internal temperature of 82°C in a pressure saucepan than when oven roasted to the same temperature. As would be expected, heat penetration was more rapid in the pressure braised muscles than in those that were oven roasted.

Cooking losses from beef top round roasts cooked by Schock et al. (1970) did not follow the expected trend of roasts heated slowly having greater cooking losses. In this case, cooking losses from oven roasted muscles were lower ($P < 0.05$) than losses from any of the other treatments, although the

cooking time was longer ($P < 0.05$) for oven roasting than for the other treatments. Losses from pressure braised (10 psig) pieces were greater ($P < 0.05$) than those from deep fat fried or oven braised pieces, even though heat penetrated faster ($P < 0.05$) in pressure braised pieces than in those given the other treatments.

Palatability. Cover (1938) emphasized the importance of slow cooking in producing tender roasts, whether the slower cooking is attained by adjustment of oven temperature or by other means.

Bramblett et al. (1959) reported that muscles of beef round cooked for 30 hours at 63°C were more tender and juicier ($P < 0.01$) than those cooked for 18 hours at 68°C as evaluated by Warner-Bratzler shear values and taste panel evaluation of tenderness and juiciness. No significant difference was found in the flavor scores for meat given the two treatments. Similar results were reported with respect to tenderness by Bramblett and Vail (1964), but U. S. Good grade round roasts cooked more rapidly were juicier on the basis of taste panel evaluation ($P < 0.05$) and press fluid yields ($P < 0.01$).

Cover (1943) concluded from an experiment described earlier in this paper that when heat penetrated beef rib, chuck, and round roasts slowly, the muscle was more tender than when heat penetration was more rapid.

Degree of doneness. The apparent degree of doneness produced by heat varies with the rate of cooking. When paired beef rib roasts are cooked at oven temperatures of 125° and 200°C to an internal temperature of 63°C , the roast cooked at 200°C will appear less well-done than the roast cooked at 125°C . The roast cooked at 200°C would have to be cooked to a higher

internal temperature than 63°C for the meat proteins to be denatured to the same extent as those in the roast cooked at 125°C to 63°C (Lowe, 1955).

Cover (1943) found that an internal temperature of 70°C yielded well-done meat when rib, chuck, and round roasts were cooked at 80°C, but an internal temperature of 80°C was necessary to produce meat of the same degree of doneness when cooking in a 125°C oven. The same trend was noted for rare beef, where an internal temperature of 58-59°C was sufficient for meat cooked at 80°C, but 63°C was necessary for meat cooked at 125°C.

Effect of End Point Temperature on Selected Characteristics of Beef

Fibers and connective tissue. The results of early work by Satorius and Child (1938) showed that the diameter of muscle fibers from beef semitendinosus muscles decreased with coagulation up to 67°C, but no difference in muscle fiber diameter was found between fibers from meat cooked to 67°C and that cooked to 75°C. They concluded that shrinkage attributable to the coagulation of muscle plasma is complete at 67°C.

Machlik and Draudt (1963) investigated the effects of time and temperature on the shear value of beef semitendinosus muscle. They found that in the temperature range of 50° to 54°C the shear values showed little change, but the collagen shrinkage reaction became apparent at 55° to 56°C when the shear values decreased. At 57° to 59°C the collagen shrinkage reaction was completed in one hour, while in the range of 60° to 65°C the reaction was completed after 15 min. Muscle fiber hardening was apparent after 1/2 to 1 hour in the range of 66° to 70°C. The hardening was complete in about 30 min in the 71° to 75°C range. Between 80° and 90°C, both collagen shrinkage and hardening of the fibers were completed after only a few minutes. The

authors concluded that the decrease in shear force for beef semitendinosus muscle in the range of 56° to 59°C is a result of the collagen shrinkage reaction and is a rate process that is highly dependent upon temperature.

Winegarden et al. (1952) studied the effects of heating strips of aponeurotic sheet, ligamentum nuchae, and deep flexor tendon connective tissue in distilled water at various temperatures for differing periods of time. In general, there was little softening at 60°C, but softening took place at about 65°C and increased with heating from 0 to 64 min at 65°C. Extensive softening occurred after only one min at 80°C. Both collagen and elastin were softened at the higher temperature. The authors suggested that long cooking times, such as used in braising and stewing, are necessary to soften coagulated fibers rather than connective tissue alone.

A decrease of 80% in the length of beef longissimus dorsi muscle fibers during heating from 55° to 65°C was reported by Hostetler and Landmann (1968). The fiber length decreased an additional 10% during heating from 65° to 80°C. The width of the muscle fibers decreased gradually with heating to 45°C, and more rapidly between 45° and 62°C, with the process appearing to be complete at 62°C.

Cooking time. As would be expected, Hunt et al. (1963) and Marshall et al. (1960) reported that the time required to cook top round beef roasts increased as the degree of doneness increased. Carlin et al. (1965) observed the same trend when cooking pork loin roasts to two internal temperatures (79.4° and 85°C).

Cooking losses. Satorius and Child (1938) found that total cooking losses from beef semitendinosus muscle increased ($P < 0.01$) as the internal

temperature increased from 58° to 67° to 75°C. Marshall et al. (1959) and Marshall et al. (1960) reported similar findings for beef top round roasts, as did Hunt et al. (1963), who found that total cooking losses increased ($P < 0.01$) with increasing internal temperature and could be expected to be approximately 52% of the raw weight for well-done meat, 43% for medium-done, and 38% for rare. Similarly, all roasts except those from the adductor and semimembranosus muscles cooked in deep fat at 100°C lost more weight during cooking when the final internal temperature increased from 55° to 70° to 85°C (Visser et al., 1960).

Carlin et al. (1965) and Weir et al. (1963) found that pork loin roasts cooked to 85°C internal temperature lost more weight during cooking than those cooked to 79.4°C.

Palatability. Visser et al. (1960) noted that tenderness scores for any of the 7 muscles used in the study were approximately the same regardless of internal temperature (55°, 70°, or 85°C), but juiciness scores usually decreased significantly as the internal temperature of the roasts increased.

Both Weir et al. (1963) and Carlin et al. (1965) reported that no significant differences in flavor intensity or initial or residual tenderness were found between pork loins roasted to 79.4° or 85°C, but roasts cooked to 79.4° were more juicy ($P < 0.01$) than those cooked to 85°C.

Webb et al. (1961) cooked pork loin roasts to internal temperatures of 65.6°, 65.6° maintained for one hour, 73.9°, and 85°C, and found that tenderness and juiciness decreased and flavor scores increased as internal temperature increased.

Degree of doneness. Bratzler (1971) stated that the visible color changes that occur during cooking are related to internal temperature. These changes are described by Bratzler as: "below 60°C, little or no color change (rare); 65° to 70°C, decreasing pinkness to 70°C (medium); at 75°C, complete loss of pinkness (well-done)." Bratzler also pointed out that meat cooked in a moist atmosphere near the temperature of boiling water has a uniform grey color with no browning of the surface.

Visser et al. (1960) noted that in order to attain meat comparable to the usual conception of rare and medium-done beef, internal temperatures of 45° and 65° were used when frying in deep fat at 100°C, rather than the temperatures of 55° and 70°C used for the other treatments.

MATERIALS AND METHODS

Six pairs of USDA Good Grade whole rounds (30.2 to 42.3 kg) were purchased from a commercial packing company. Seven days postmortem, the top round was separated, the outside fat covering removed, and the semimembranosus and adductor muscles were divided into three roasts as illustrated in Figure 1. Weights of the roasts ranged from 708 to 1666 g, and dimensions of roasts, in cm, were: length, 17 to 26; width, 5 to 11; and depth, 6 to 10. At the time of cutting, all roasts were wrapped in oven film bags (nylon 66 with a heat stabilizer) and frozen in a blast freezer at -26°C. They were stored 3 to 10 weeks in an upright household freezer at an average temperature of -22°C.

At each of 12 evaluation periods three roasts were cooked from the frozen state by dry or moist heat in a rotary hearth gas oven maintained

at 177° or 205°C to end point temperatures of 60°, 70° or 80°C as specified by the experimental design (Table 1).

The design was a split plot with three replications in which the two oven temperatures were the main plots and the type of heat and end point temperatures (six treatment combinations) were the sub plots.

A hole was bored into the center of each roast so that a centigrade thermometer could be inserted. Roasts cooked by dry heat were removed from the oven film bags and placed on a low rack in a shallow roasting pan. Roasts cooked by moist heat remained in the bags and six slits (approximately 3.7 cm long) were made in the top of each bag to allow for the escape of steam and prevent the bag from breaking (Figure 2).

Rate of Heat Penetration, Cooking Time and Losses

The rate that heat penetrated the muscle was observed by recording the time, in minutes, required for the internal temperature of each roast to reach 0°C, to increase from 0° to 10°C, and for each 5°C increase between 10°C and the end point temperature. Total cooking time, in minutes, was recorded and cooking time in min/kg was calculated.

Percentage total, volatile, and dripping losses, based on the weight of the frozen roast were calculated for roasts cooked by dry heat. Percentages of total and dripping losses were calculated for roasts cooked by moist heat. Drippings from all roasts were collected in 250-ml graduated cylinders and allowed to stand 45 min. After the fat had stabilized at the top of the drippings, the total volume of drippings and the volume of fat were read, and the percentage fat in the drippings was calculated.

Table 1-Experimental design

Cooking period	Replication	Animal number	Roast number	Treatment ^a	Oven temp., °C
1	1	1	aL	III	177
		1	bL	II	177
		1	cL	IV	177
2	1	1	dR	VI	177
		1	eR	V	177
		1	fR	I	177
3	1	2	aL	IV	205
		2	bL	III	205
		2	cL	VI	205
4	1	2	dR	II	205
		2	eR	V	205
		2	fR	I	205
5	2	3	aL	V	177
		3	bL	IV	177
		3	cL	III	177
6	2	3	dR	II	177
		3	eR	VI	177
		3	fR	I	177
7	2	4	aL	I	205
		4	bL	IV	205
		4	cL	V	205
8	2	4	dR	VI	205
		4	eR	II	205
		4	fR	III	205
9	3	5	aL	II	177
		5	bL	III	177
		5	cL	V	177
10	3	5	dR	IV	177
		5	eR	I	177
		5	fR	VI	177
11	3	6	aL	I	205
		6	bL	IV	205
		6	cL	II	205
12	3	6	dR	V	205
		6	eR	VI	205
		6	fR	III	205

^aTreatment I 60°C Dry heat
 II 70°C Dry heat
 III 80°C Dry heat
 IV 60°C Moist heat
 V 70°C Moist heat
 VI 80°C Moist heat

**THIS BOOK
CONTAINS
NUMEROUS PAGES
THAT WERE
BOUND WITHOUT
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Fig 1-Plan for division of top round into three roasts and sampling plan for individual roasts

1. Distal shear core (1.3-cm) and water-holding capacity (WHC)
2. Central shear core (1.3-cm) and water-holding capacity (WHC)
3. Proximal shear core (1.3-cm) and water-holding capacity (WHC)
4. Total moisture and Gardner color-difference
5. Apparent degree of doneness (1.3-cm slice)
6. Palatability samples (1.3-cm cubes)

aL

bL Sections a, b, c of top round, left side of carcass

cL

dR

eR Sections d, e, f of top round, right side of carcass

fR

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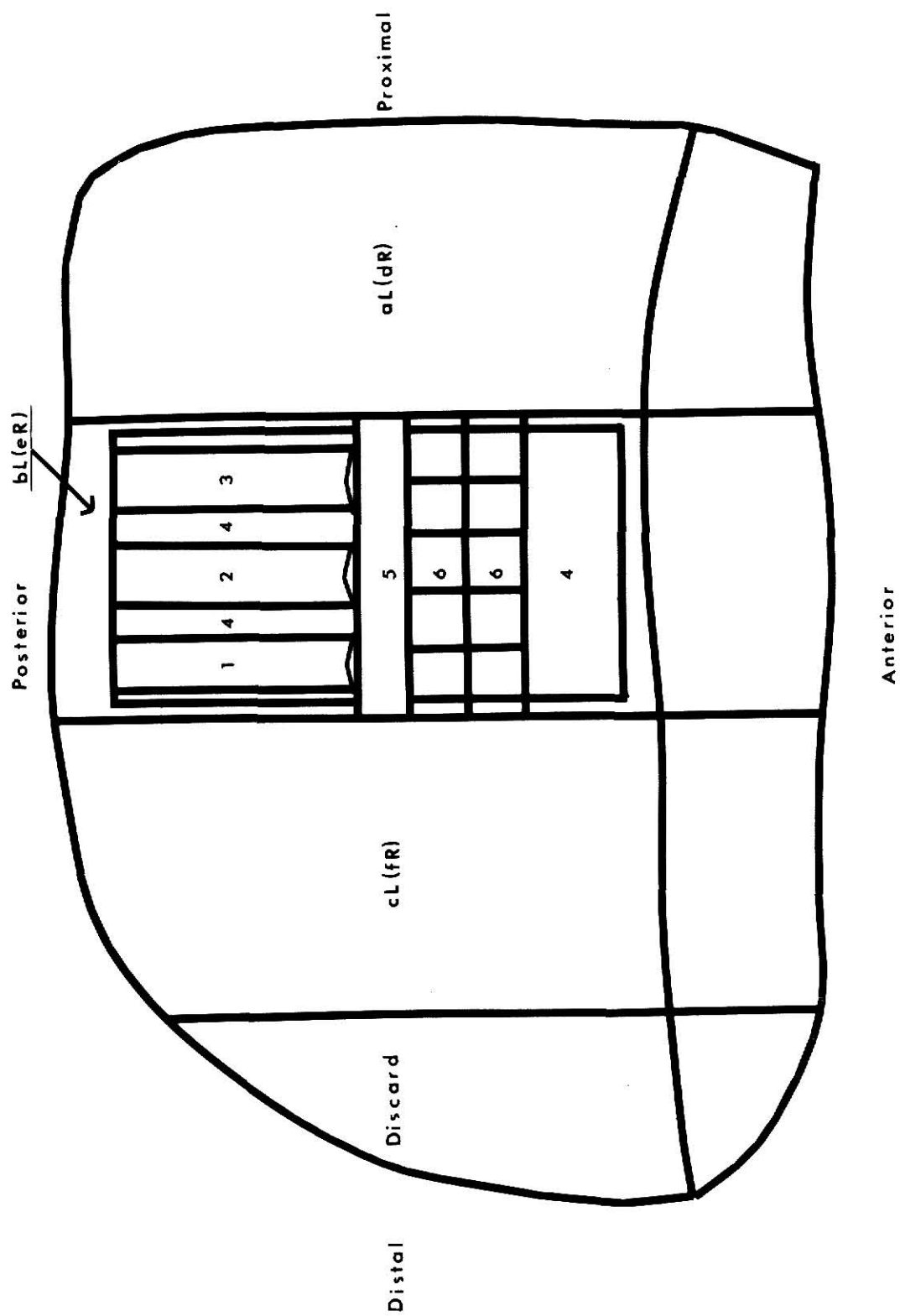


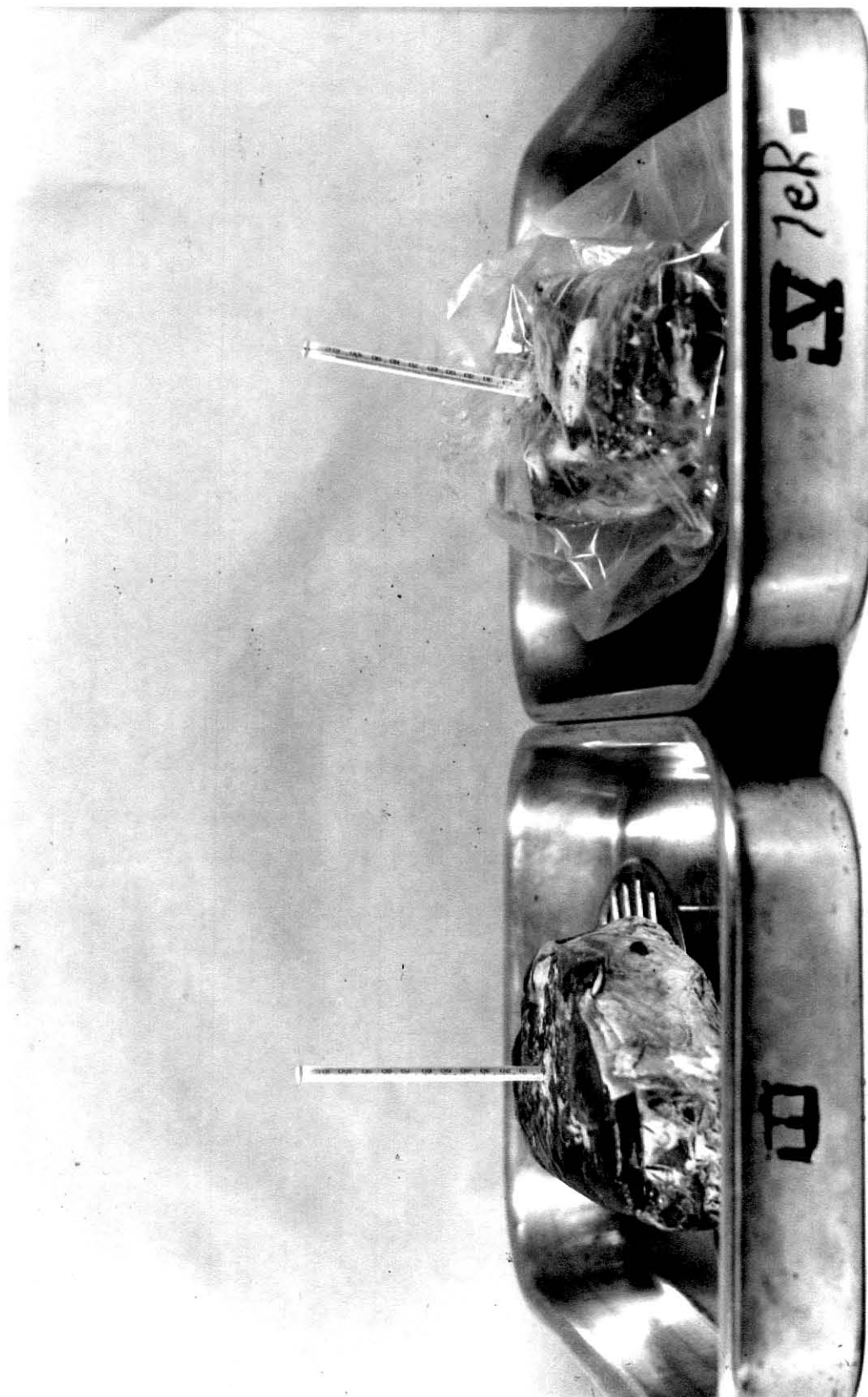
Fig 2-Beef top round roasts prepared for cooking

A Dry Heat

B Moist Heat

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A

B

Post-oven Temperature Rise and Objective Measurements on Cooked Muscle

The maximum post-oven internal temperature, °C, of each roast, and the time required to reach that temperature was recorded. Roasts cooked by moist heat remained in the oven film bags during that period. Samples for measurements on cooked muscle were taken from roasts at the locations indicated in Figure 1.

Tenderness was measured by shearing three 1.3-cm cores (proximal, central, and distal positions) on a Warner-Bratzler shearing apparatus with a 11.4-kg dynamometer. Triplicate measurements were made on each core, and the overall shear value was the average of the three shear cores.

Triplicate measurements for water-holding capacity (WHC) were made by the method of Miller and Harrison (1965) on 0.3-g samples from the center of the cores used for Warner-Bratzler shear values. The ratio of the area of pressed muscle to the area of expressed liquid marked on filter paper on which the sample was pressed was designated as the expressible-liquid index. Values for WHC were obtained by subtracting the expressible-liquid index from 1.0, arbitrarily chosen as the maximum expressible-liquid index. Because the expressible-liquid index is inversely related to the amount of liquid expressed from the sample, the larger the value for WHC, the greater the amount of liquid expressed.

Percentage total moisture was measured by drying 10-g samples of ground muscle in a C. W. Brabender Semi-Automatic Rapid Moisture Tester for 60 min at 121°C.

Color-difference was measured with a Gardner Color Difference Meter standardized using a satin finish ceramic tile with calculated values of: Rd (reflectance), 38.0; a+ (redness), 6.6; and b+ (yellowness), 14.7.

Approximately 25 g of cooked, ground muscle were packed in a plexiglass cell so that light could not filter through the sample. Duplicate measurements were made for each color-difference factor. After the first measurement, the cell was rotated 90° for the second measurement.

Sensory Evaluation

Six experienced panel members evaluated each roast for desirability of flavor and overall acceptability and intensity of juiciness and tenderness using a 7-point scale with 7 being the most desirable or intense (Form I, Appendix, p. 55). A slice of muscle covered with a transparent household plastic wrap was placed under a MacBeth Skylight and rated as rare, 1; medium-done, 2; or well-done, 3. Instructions for evaluation were given to panel members during preliminary work (Form II, Appendix, p. 56). Panel members selected at random 1.3-cm cubes of muscle that were placed in the top of 1-pint enamel double boilers and set over hot water. The entire system was held at a constant low heat ($35^{\circ}\text{C} \pm 1^{\circ}\text{C}$) on an electric hot tray until the samples were evaluated by all panel members (not more than 30 min).

Analysis of Data

The analysis of variance used to analyze the data was:

Source of variation		D/F
Oven temperature		1
Error (A)		4
Treatment combinations		5
Type of heat	1	
End point temperature	2	
Type of heat x end point temperature	2	
Oven temperature x type of heat		1
Oven temperature x end point temperature		2
Oven temperature x end point temperature x type of heat		2
Error (B)		<u>20</u>
Total		35

RESULTS AND DISCUSSION

Initial Weight of Roasts, Rate of Heat Penetration

Analysis of variance indicated no significant differences among weights of the roasts assigned to the two types of heat, the three end point temperatures, or the two oven temperatures (Tables 2, 3, and 4).

The time required to raise the internal temperature from the initial temperature to 10°C was greater ($P < 0.05$) for roasts cooked by moist heat than by dry heat (Table 2), but that period of cooking was not affected significantly by end point or oven temperature (Tables 3 and 4).

Details of mean data in Tables 2, 3, and 4 can be observed in the rate of heat penetration curves (Figures 3 and 4) and in Table 9, Appendix p. 64. With both moist and dry heat at both oven temperatures, heat penetrated the muscle at a fairly constant rate. At both oven temperatures, the internal temperature of roasts cooked by moist heat increased more rapidly than the internal temperature of those cooked by dry heat. There were no significant differences between dry and moist heat for the time required for each 5°C increase from 15° through 35°C.

Less ($P < 0.05$ to $P < 0.001$) time was required to increase the internal temperature from 35° to 40°C and from 45° through 80°C when cooking by moist heat than by dry heat. The magnitude of difference increased from 0.78 min/5°C at 45°C to 4.83 min/5°C at 80°C. With both dry and moist heat at the two oven temperatures, the average time for a 5°C increase in internal temperature was similar for all three end point temperatures.

The rate of heat penetration was more rapid ($P < 0.05$) between 65° and 70°C and between 75° and 80°C when roasts were cooked at 205°C than when

Table 2-Means and F-values for type of heat^a

Measurement	Type of heat		Difference	F-value
	Dry	Moist		
Initial weight, kg	1.08	1.16	0.08	2.24 ns
Rate of heat penetration, min				
Initial temp to 10°C	58.44	68.39	9.95	11.65 *
Min/5°C, 10°C to end point	4.90	3.28	1.62	--
Cooking time				
Total, min	112.39	107.83	4.56	1.79 ns
Min/kg	104.88	94.83	10.05	14.39 **
Cooking losses, %				
Total	27.69	34.86	7.17	132.85 ***
Dripping	2.16	19.06	16.90	372.94 ***
Volume of drippings, ml	7.78	197.78	190.00	123.06 ***
Lipid in drippings, % of volume	18.14	4.05	14.09	12.43 **
Total moisture, %	67.03	63.63	3.40	49.06 ***
Water-holding capacity ^b	0.8014	0.7636	0.0378	11.70 **
Shear value, kg/1.3-cm core	3.4	3.7	0.3	0.51 ns
Color-difference, Gardner				
Rd (reflectance)	20.15	20.54	0.39	0.60 ns
a+ (redness)	6.05	2.59	3.46	46.06 ***
b+ (yellowness)	10.50	10.49	0.01	0.00 ns
Sensory scores				
Flavor ^c	5.4	5.7	0.3	1.80 ns
Juiciness ^c	5.3	4.7	0.6	2.30 ns
Tenderness ^c	5.7	5.3	0.4	4.44 *

Table 2-(concluded)

Measurement	Type of heat		Difference	F-value
	Dry	Moist		
Sensory scores				
Overall acceptability ^c	5.3	5.1	0.2	1.75 ns
Apparent degree of doneness ^d	2.0	2.6	0.6	16.87 ***

^aEnd point and oven temperature data combined

^b1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^c7-(extremely desirable, juicy or tender); 1-(extremely undesirable, dry or tough)

^d3-well-done; 2-medium-done; 1-rare

* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

Table 3-Means, F-values, and LSD's for end point temperatures^a

Measurement	End point temperature, °C			F-value	LSD
	60	70	80		
Initial weight, kg	1.10	1.12	1.15	0.40 ns	---
Rate of heat penetration, min					
Initial temp to 10°C	63.33	62.00	64.92	0.33 ns	
Min/5°C, 10°C to end point	3.62	3.72	3.91	---	
Cooking time	*				
Total, min	99.42	107.25 *	123.67	11.69 ***	10.68
Min/kg	91.34 *	98.29 *	109.94	16.79 ***	6.76
Cooking losses, %	*				
Total	27.91 *	31.59 *	34.32	35.67 ***	1.59
Dripping	10.83	12.24 *	8.76	5.33 *	2.24
Volatile	21.04 *	24.98 *	30.15	40.53 ***	2.34
Volume of drippings, ml	101.67	125.83	80.83	2.31 ns	---
Lipid in drippings, % of volume	8.85	6.59	17.85	2.96 ns	---
Total moisture, %	66.95 *	65.32 *	63.72	14.97 **	1.23
Water-holding capacity ^b	0.7931	0.7835	0.7708	1.37 ns	---
Shear value, kg/1.3-cm core	3.13	3.85	3.71	1.45 ns	---
Color-difference, Gardner	*				
Rd (reflectance)	19.73	19.90 *	21.41	4.40 *	1.30
a+ (redness)	6.30 *	4.19 *	2.47	18.78 ***	1.30
b+ (yellowness)	10.63	10.65	10.19	0.82 ns	---
Sensory scores					
Flavor ^c	5.4	5.6	5.6	0.30 ns	---
Juiciness ^c	5.2	5.5	4.4	2.85 ns	---

Table 3-(concluded)

Measurement	End point temperature, °C			F-value	LSD
	60	70	80		
Sensory scores					
Tenderness ^c	5.6	5.4	5.4	0.29 ns	---
Overall acceptability ^c	5.2	5.3	5.0	1.98 ns	---
Apparent degree of doneness ^d	2.1	2.1	2.4	2.11 ns	---

^a Dry and moist heat and oven temperature data combined

^b 1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^c 7-(extremely desirable, juicy or tender); 1-(extremely undesirable, dry or tough)

^d 3-well-done; 2-medium-done; 1-rare

* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

Table 4-Means and F-values for oven temperatures^a

Measurement	Oven temperature, °C		Difference	F-value
	177	205		
Initial weight, kg	1.08	1.16	0.08	0.15 ns
Rate of heat penetration, min				
Initial temp to 10°C	67.39	59.44	7.95	0.77 ns
Min/5°C, 10°C to end point	4.38	3.77	0.61	---
Cooking time				
Total, min	115.83	104.39	1.44	0.71 ns
Min/kg	107.64	92.07	15.57	4.51 ns
Cooking losses, %				
Total	31.13	31.39	0.23	0.05 ns
Dripping	11.90	9.32	2.58	2.29 ns
Volatile	24.10	26.68	2.58	2.09 ns
Volume of drippings, ml	111.28	94.28	17.00	0.99 ns
Lipid in drippings, % of volume	13.18	9.02	4.16	1.08 ns
Total moisture, %	65.26	65.40	0.14	0.09 ns
Water-holding capacity ^b	0.7773	0.7876	0.0103	0.87 ns
Shear value, kg/1.3-cm core	3.3	3.8	0.5	1.51 ns
Color-difference, Gardner				
Rd (reflectance)	21.08	19.61	1.47	1.43 ns
a+ (redness)	4.26	4.37	0.11	0.04 ns
b+ (yellowness)	10.34	10.65	0.31	0.90 ns
Sensory scores				
Flavor ^c	5.5	5.6	0.1	0.51 ns
Juiciness ^c	5.1	4.9	0.2	0.45 ns
Tenderness ^c	5.5	5.4	0.1	0.32 ns

Table 4--(concluded)

Measurement	Oven temperature, °C		Difference	F-value
	177	205		
Sensory scores				
Overall acceptability ^c	5.2	5.2	0.1	0.15 ns
Apparent degree of doneness ^d	2.2	2.3	0.1	0.01 ns

^aDry and moist heat and end point temperature data combined

^b1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^c7-(extremely desirable, juicy or tender); 1-(extremely undesirable, dry or tough)

^d3-well-done; 2-medium-done; 1-rare

* $P \leq 0.05$ ** $P \leq 0.01$ *** $P \leq 0.001$

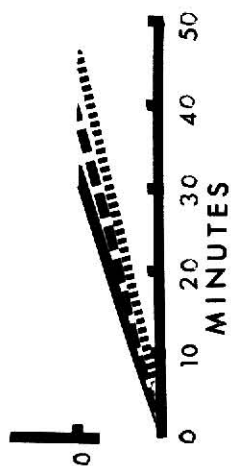


Fig. 3-Rate of heat penetration from initial temperature to 0°C and from 0° to 60°, 70°, or 80°C for top round roasts cooked by moist and dry heat at 177°C.

OVEN TEMP. - 177° C

DRY HEAT

— 60° C
 - - - 70° C
 80° C



MOIST HEAT

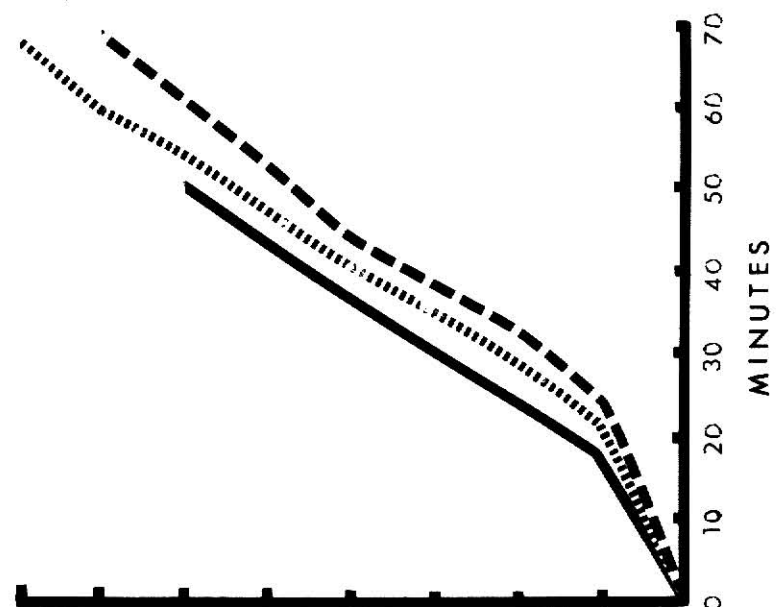
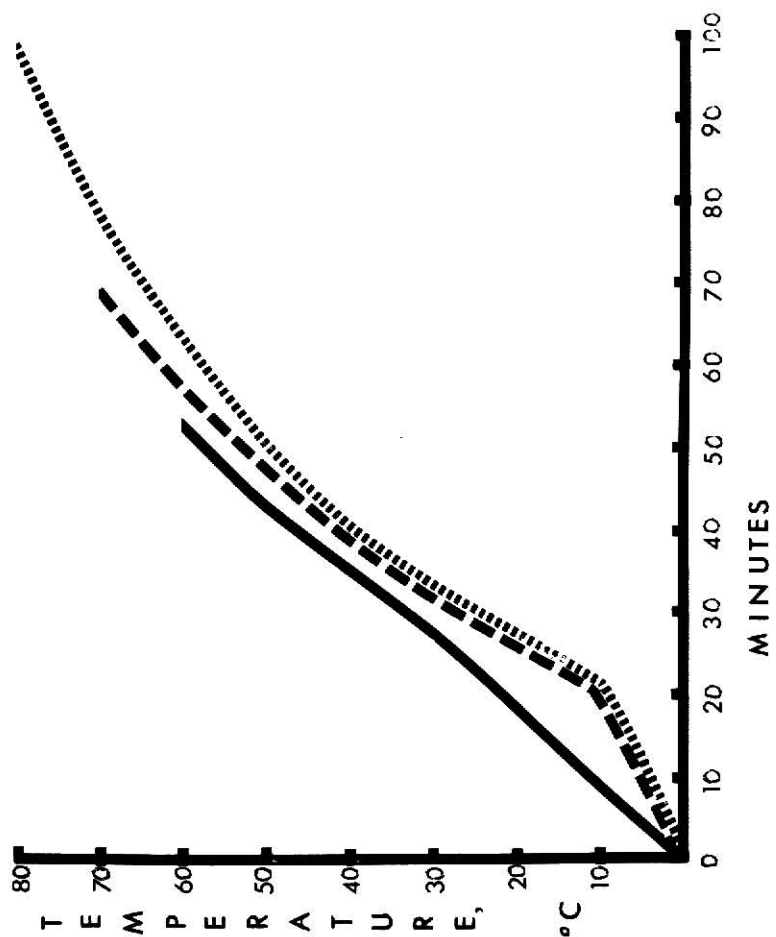
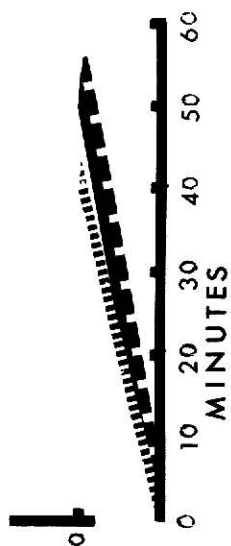
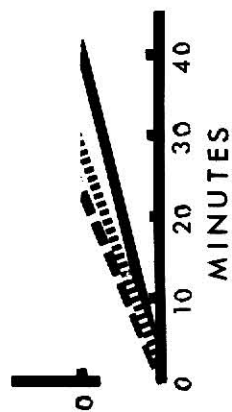


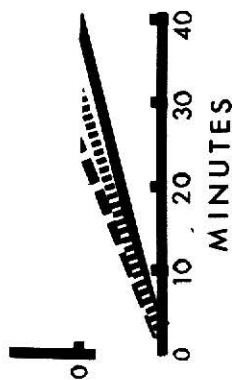
Fig. 4-Rate of heat penetration from initial temperature to 0°C and from 0° to 60°, 70°, or 80°C for top round roasts cooked by moist and dry heat at 205°C.

OVEN TEMP. - 205° C

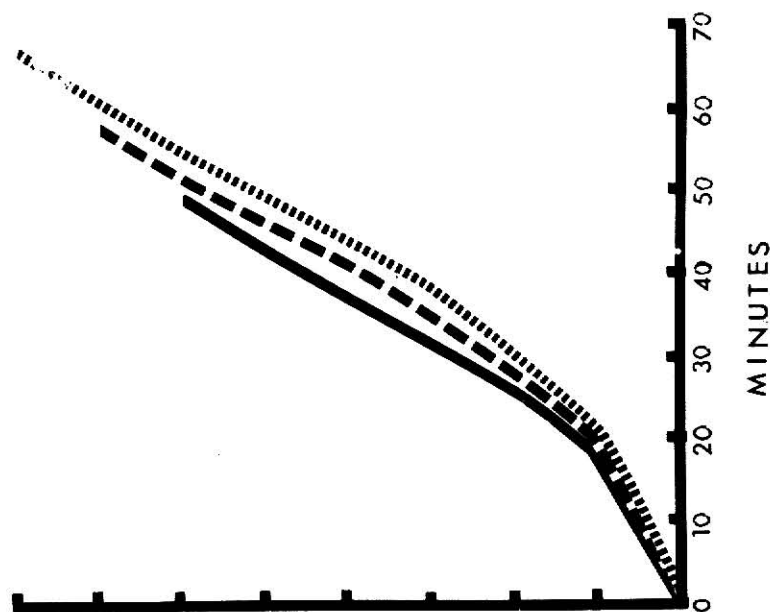
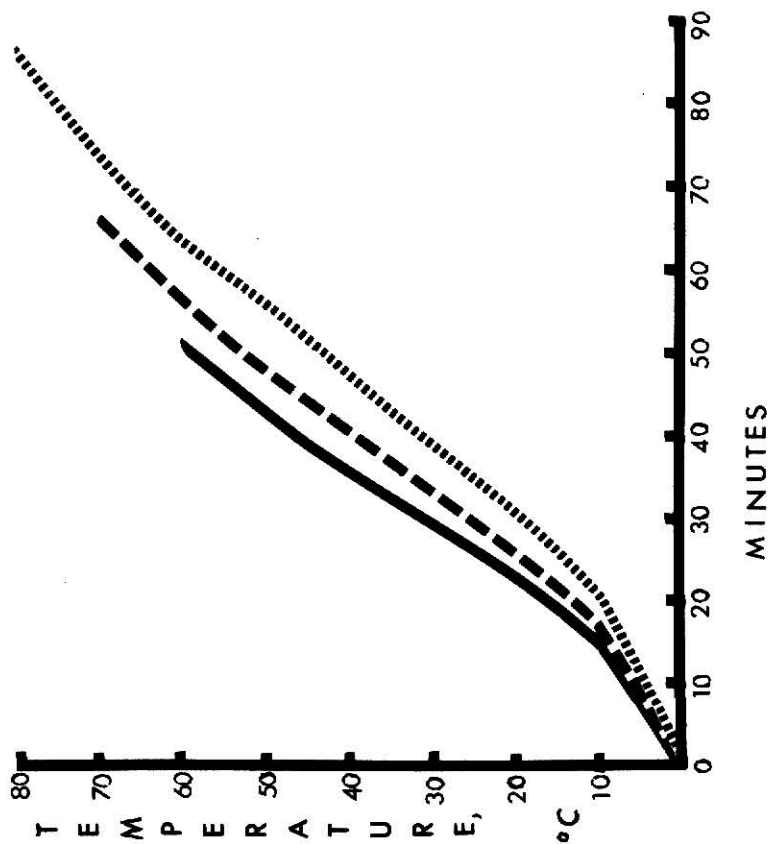
DRY HEAT



MOIST HEAT



— 60° C
 - - - 70° C
 80° C



cooked at 177°C. There were no other differences attributable to oven temperature.

Type of Heat

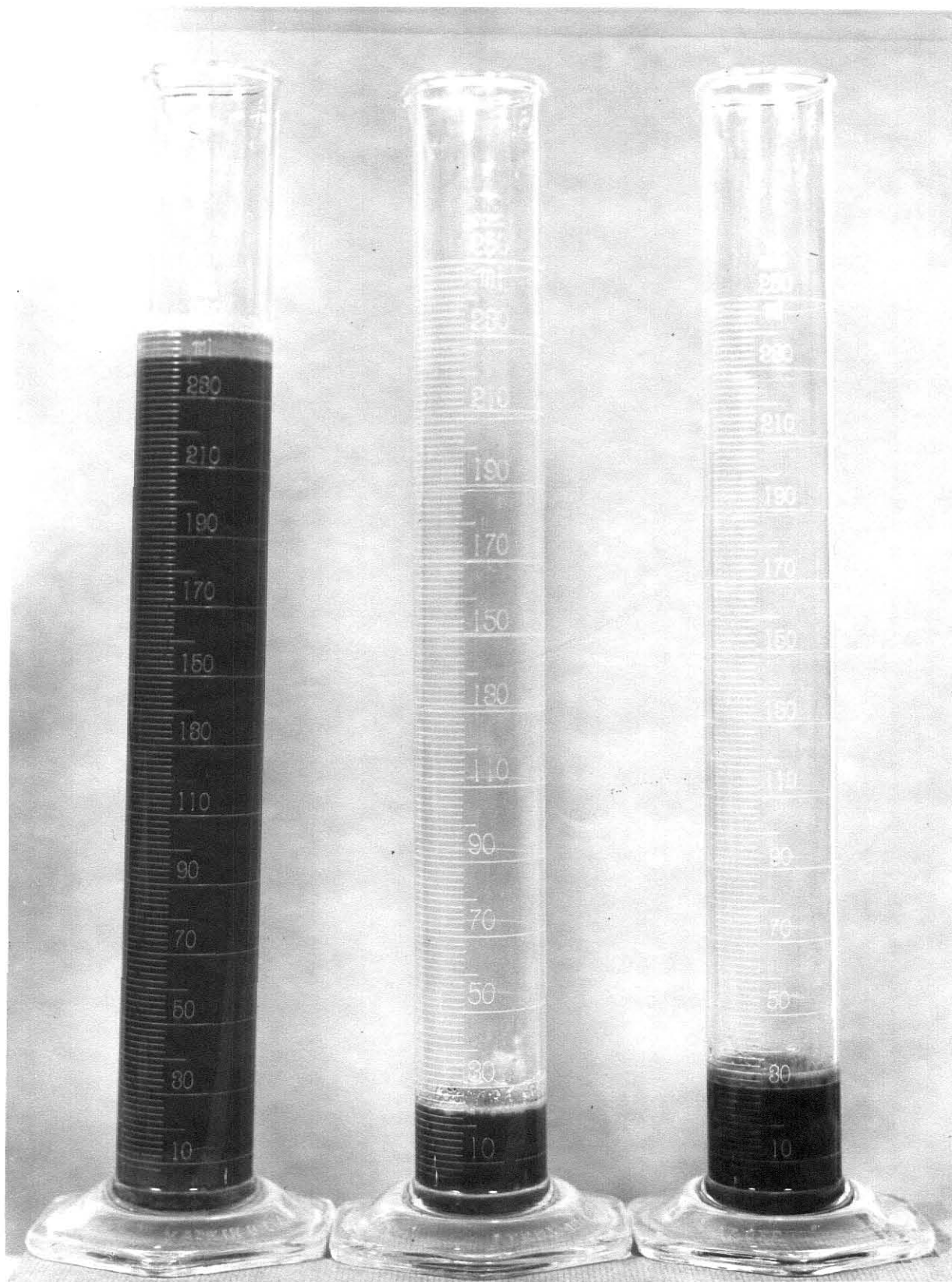
Measurements affected ($P < 0.001$) by type of heat were: percentage total and dripping cooking losses, volume of drippings, percentage total moisture, Gardner a+ (redness) values, and apparent degree of doneness scores (Table 2). Percentage total and dripping cooking losses and the volume of drippings were less for roasts cooked by dry heat than for those cooked by moist heat (Figure 5), whereas percentage total moisture was greater in roasts cooked by dry heat. Both Gardner a+ (redness) values and apparent degree of doneness scores indicated that roasts cooked by dry heat were redder (appeared less well-done) than roasts cooked by moist heat.

The type of heat also affected ($P < 0.01$) cooking time in min/kg, percentage fat in the drippings and WHC (Table 2). Although on the basis of min/kg cooking time was longer for dry than for moist heat, the total cooking time (min) was not affected significantly by type of heat (Table 2). Other measurements on which the type of heat had no significant effect were: Gardner Rd (reflectance) and b+ (yellowness) values, flavor, juiciness, and overall acceptability scores. Roasts cooked by dry heat were scored more tender ($P < 0.05$) and juicier than those cooked by moist heat. Although the magnitude of difference between dry and moist heat was greater for juiciness than for tenderness, the difference between the two types of heat was statistically significant for tenderness, but not for juiciness. This may be explained by the fact that the mean square error term for juiciness was 4 times greater than that for tenderness. Ferger et al. (1972) also found that at oven temperatures of 149° and 177°C beef rib roasts cooked by dry heat

Fig. 5-Volume of drippings, ml

A Moist Heat

B Dry Heat



A

B

were slightly more tender and juicier than those cooked by moist heat in 3M Scotchpak Oven Service Film.

Total cooking losses were less ($P < 0.001$) for dry than for moist heat, despite the longer cooking time required with dry heat. Similarly, Schock et al. (1970) found that although the cooking time was longer for oven roasted pieces of beef semimembranosus muscle than for oven braised, deep fat fried, or pressure braised pieces, losses from oven roasted pieces were lower ($P < 0.05$) than losses from any of the other pieces. They also reported that percentage total moisture was higher in oven roasted beef than in oven braised beef. Moreover, Hood (1960) reported that beef triceps brachii roasts cooked by dry heat required longer cooking time, but lost less weight during cooking than those wrapped in heavy aluminum foil during cooking. Dripping losses from roasts cooked by moist heat were greater than those from roasts cooked by dry heat (Hood, 1960).

End Point Temperature

Total cooking time, cooking time in min/kg, percentage total, dripping and volatile losses, percentage total moisture and Gardner Rd (reflectance) and a^* (redness) values were affected significantly by end point temperature of the roasts (Table 3). Cooking time, both total and min/kg, increased with each 10°C increase in end point temperature. Differences in cooking time among end point temperatures were significant ($P < 0.05$) except for the difference in total minutes between 60° and 70°C . Also, percentage total and volatile cooking losses increased significantly ($P < 0.05$) with increasing end point temperature from 60° to 80°C , whereas dripping losses increased slightly between 60° and 70°C , then decreased ($P < 0.05$) between 70° and 80°C .

As would be expected, percentage total moisture was inversely related to volatile losses. Moisture was greatest in roasts cooked to 60°C, and decreased ($P < 0.05$) with each succeeding increase in end point temperature; whereas volatile losses were least for roasts cooked to 60°C and increased ($P < 0.05$) with each 10°C increase in end point temperature.

Gardner Rd and a+ values indicate that the meat became lighter (Rd values) and lost redness (a+ values) with increase in end point temperature between 60° and 80°C. Rd (reflectance) values increased significantly ($P < 0.05$) between 60° and 80°C and between 70° and 80°C, whereas Gardner a+ (redness) values decreased ($P < 0.05$) between each increasing end point temperature. Differences in Gardner b+ (yellowness) values attributable to end point temperature were not significant.

The end point temperature did not affect significantly volume of drippings, percentage fat in drippings, WHC, and Warner-Bratzler shear values. Likewise, none of the sensory measurements were affected significantly by the end point temperatures of the roasts (Table 3).

Hood et al. (1955) broiled beef biceps femoris steaks to 71.1° and 80°C, and found that steaks cooked to 71.1°C were juicier than those cooked to 80°C, but there was no significant difference in tenderness or flavor of steaks cooked to those end points.

Similar to the results of this study, Visser et al. (1960) reported that as the internal temperature of beef roasts from seven muscles increased, the average cooking time and percentage total cooking losses also increased. In contrast to the findings of this study, they found that average tenderness scores and shear values did not differ significantly among end point

temperatures, but juiciness scores and press fluid yields generally decreased as the end point temperature increased.

Oven Temperature

None of the measurements were affected significantly by oven temperature (Table 4). Although cooking time was slightly shorter when roasts were cooked at the higher oven temperature, total cooking losses averaged practically the same for the two oven temperatures.

Similarly, Ferger et al. (1972) compared three oven temperatures for cooking beef roasts from the frozen state by dry or moist heat (in oven film) and found that the time required for cooking was not shortened significantly by raising the oven temperature above what generally recommended.

Type of Heat x End Point Temperature Interactions

Data in Table 5 for type of heat x end point temperature interactions help explain some of the data in Tables 2, 3, and 4. The interaction between those two parameters was significant ($P < 0.05$) for both total minutes and min/kg cooking time, percentage dripping cooking losses, percentage total moisture, and sensory scores for flavor; significant ($P < 0.01$) for percentage total cooking losses and apparent degree of doneness scores; and significant ($P < 0.001$) for Gardner a^* (redness) values (Table 5).

Significant differences in total cooking time between 70° and 80°C (Table 3) are attributable to the effects of dry heat (Table 5). The only significant ($P < 0.05$) difference in total cooking time between dry and moist heat was for roasts cooked to 80°C. However, this difference was not large enough for a difference to be detected when only type of heat was considered (Table 2). When cooking time was expressed in min/kg, significant

Table 5-Means, F-values, and LSD's for significant type of heat x end point temperature interactions

Measurement	Type of heat	End point temperature, °C			F-value	LSD
		60	70	80		
Cooking time		*				
Total, min	Dry	96.17	107.00	134.00	3.89 *	15.10
	Moist	102.67	107.50	113.33		
Min/kg	Dry	91.14 *	104.69 *	118.80	4.17 *	9.57
	Moist	91.54	91.89	101.07		
Cooking losses, %		*				
Total	Dry	22.98 *	27.92 *	32.19	6.79 **	2.24
	Moist	32.85	35.27	36.45		
Dripping	Dry	1.84 *	2.60 *	2.04	4.08 *	3.16
	Moist	19.81	21.88	15.48		
Total moisture, %		*				
	Dry	69.25 *	67.33 *	64.51	3.68 *	1.74
	Moist	64.65	63.32	62.93		
Color-difference, Gardner		*				
a+ (redness)	Dry	9.69 *	5.68 *	2.78	12.32 ***	1.84
	Moist	2.90	2.70	2.15		
Post-oven temperature rise, °C						
	Dry	0.3	0.0	0.0	---	---
	Moist	7.8	5.6	0.8		
Sensory scores		*				
Flavor ^a	Dry	5.0 *	5.3	5.9	6.15 *	0.64
	Moist	5.8	5.8	5.3		

Table 5--(concluded)

Measurement	Type of heat	End point temperature, °C			F-value	LSD	
		60	70	80			
Sensory scores		*					
Apparent degree of doneness ^b	Dry	1.6	1.8	*	2.5	6.07 **	0.53
		*	*				
	Moist	2.6	2.7		2.4		

^a7--(extremely desirable, juicy or tender); 1--(extremely undesirable, dry or tough)

^b3--well-done; 2--medium-done; 1--rare

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

differences occurred between each end point temperature for dry heat, and between dry and moist heat at internal temperatures of 70° and 80°C. Those differences between dry and moist heat indicate that the use of cooking bags did decrease the time required for cooking roasts to 70° and 80°C by approximately 13 to 17 min/kg. In contrast to those results, data from this laboratory for both leg of lamb (end point, 75°C) and boneless beef rib roasts (end point 60°C) indicated that the use of 3M Scotchpak Oven Service Film for cooking by moist heat did not reduce cooking time (Ferguson et al., 1972). With moist heat, there were no significant differences in min/kg attributable to end point temperature (Table 5).

Percentage total cooking losses were greater ($P < 0.05$) for moist heat than for dry heat at all three end point temperatures, but the magnitude of difference between the two types of heat decreased at each 10°C increment in end point temperature. Percentage dripping cooking losses were greater ($P < 0.05$) for moist heat than for dry heat at each end point. Values for both treatments increased between 60° and 70°C, then decreased between 70° and 80°C, with the decrease being significant ($P < 0.05$) for moist heat. This accounts for the significant ($P < 0.05$) decrease in dripping losses between 70° and 80°C values for data summarized on the basis of end point temperatures (Table 3).

Percentage total moisture decreased ($P < 0.05$) at each end point temperature when roasts were cooked by dry heat. The values for roasts cooked by moist heat followed the same trend, although differences between end points were not significant. Therefore, it may be concluded that significant differences in total moisture among end point temperatures found in Table 3 are attributable to the effects of dry heat cooking. Roasts cooked to 60°

and 70°C by dry heat contained more ($P < 0.05$) moisture than those cooked by moist heat. The difference at 80°C was not significant. This indicates that the significant ($P < 0.01$) difference in moisture between dry and moist heat seen in Table 2 is attributable to the differences at 60° and 70°C.

Gardner a^+ (redness) values were greatest for roasts cooked by dry heat to 60°C and decreased ($P < 0.05$) as the internal temperature was increased to 70° and 80°C. There were no significant differences among a^+ values for roasts cooked by moist heat, which indicates that the differences among end point temperatures found in Table 3 are attributable principally to the effects of the dry heat treatment. The values for moist heat were less ($P < 0.05$) than those for dry heat at 60° and 70°C, which contributed to the significant ($P < 0.001$) differences between a^+ values for dry and moist heat seen in Table 2.

There were significant interactions between type of heat and end point temperature for two sensory characteristics, flavor and apparent degree of doneness. The panel preferred the flavor of meat cooked by moist heat to 60° and 70°C, with the difference between dry and moist heat being significant ($P < 0.05$) at 60°C. However, they preferred meat cooked by dry heat to 80°C, although the difference between the two types of heat were not significant. Roasts cooked by moist heat appeared medium- to well-done at all three end point temperatures. Apparent degree of doneness scores for meat cooked by dry heat were less ($P < 0.05$) than those for roasts cooked by moist heat to internal temperatures of 60° and 70°C. This suggests that the flavor of the meat was more desirable to this taste panel when it appeared more well-done.

Apparent Degree of Doneness, Post-Oven Temperature Rise

Apparent degree of doneness scores were higher ($P < 0.001$) for roasts cooked by moist heat than for those cooked by dry heat, and were not affected by oven temperature or end point temperature. Roasts cooked by dry heat to an internal temperature of 60°C appeared bright red in the center (5 to 7 cm diameter) with the red color fading to grey-brown around the edges, and those roasts exuded red juice upon standing. Roasts cooked by dry heat to 70°C were pink in the center (3 to 4 cm diameter), fading rapidly to grey-brown about halfway through the roast. The roasts cooked to 80°C by dry heat generally were slightly pink in the center (2 to 3 cm diameter), but faded quickly to grey-brown throughout the rest of the roast. The surface of roasts cooked by dry heat was a rich, dark brown, and the surface texture was fine-grained.

Roasts cooked by moist heat to an internal temperature of 60°C were slightly pink in the center (2 to 3 cm diameter), fading quickly to light grey-brown in the rest of the roast. Those cooked by moist heat to 70° and 80°C were uniformly grey-brown throughout the roast. The surface of roasts cooked by moist heat was grey-brown rather than the rich, dark brown of the oven roasted meat, and the surface texture of the muscle appeared coarse.

Post-oven temperature rise was observed most frequently when roasts were cooked by moist heat. Those roasts remained in the oven film bags during observation of post-oven temperature rise. The greatest increase in temperature (mean = 7.8°C) occurred in roasts cooked to 60°C by moist heat. Roasts cooked to 70°C by moist heat followed with a 5.6°C mean post-oven temperature rise. Roasts cooked by moist heat to 80°C and by dry heat to 60°C both averaged less than 1°C increase, and those cooked by dry heat to 70°

and 80°C never exhibited post-oven temperature rise. Time required to reach the final post-oven temperature ranged from 8.5 to 28 minutes. The post-oven temperature rise observed for roasts cooked to 60° and 70°C by moist heat may account partially for the lack of pinkness in the meat that usually is expected, but was not observed, at those end point temperatures. Greater post-oven temperature rise at lower end point temperatures also was reported by Rogers et al. (1967), who found that post-oven temperature rise observed in turkey breast and thigh-leg pieces was greatest at 25°C internal temperature and generally decreased with each 10°C increment in end point temperature from 25° to 55°C.

SUMMARY

Thirty-six top round beef roasts (SM and AD muscles) were cooked by dry heat in open pans and by moist heat in oven film cooking bags at 177° or 205°C to internal temperatures of 60°, 70°, or 80°C, and evaluated by selected objective and sensory measurements. A split-plot design was followed to cook and evaluate the roasts, and data were analyzed by analysis of variance with least significant differences at the 5% level calculated when F-values were significant.

Percentage total and dripping cooking losses and the volume of drippings were less ($P < 0.001$) for roasts cooked by dry heat than for those cooked by moist heat. Percentage total moisture was greater ($P < 0.001$) and roasts were more tender ($P < 0.05$) when cooked by dry heat.

Cooking time increased ($P < 0.05$) between 60° and 80°C and between 70° and 80°C. Percentage total and volatile cooking losses increased ($P < 0.05$) with increasing end point temperature, but dripping losses increased slightly

between 60° and 70°C, then decreased ($P < 0.05$) between 70° and 80°C. Percentage total moisture was greatest in roasts cooked to 60°C. Gardner Rd (reflectance) values increased ($P < 0.05$) between 60° and 80°C and between 70° and 80°C, whereas a^+ (redness) values decreased ($P < 0.05$) with each increase in end point temperature. No sensory characteristic was affected by end point temperature or oven temperature; no objective measurement was affected by oven temperature.

Interactions between type of heat and end point temperature indicate that differences ($P < 0.01$) in percentage total moisture between dry and moist heat were attributable to differences at 60° and 70°C. Differences among end point temperatures for Gardner a^+ (redness) values were attributable principally to dry heat. Flavor and apparent degree of doneness scores showed that the panel preferred the flavor of the meat that appeared more well-done.

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APPENDIX

Form I.

SCORE CARD FOR BEEF TOP ROUND ROAST
(Semimembranosus and Adductor Muscles)

Project 5-944, 1972

Panel Member _____ Code _____ Date _____

Sample No.	Desirability of Flavor	Tenderness		Juiciness	Overall Acceptability	Degree of Doneness
		No. chews	Score			

Desirability of flavor
 7 Extremely desirable
 6 Desirable
 5 Moderately desirable
 4 Acceptable
 3 Slightly undesirable
 2 Undesirable
 1 Extremely undesirable

Tenderness
 7 Extremely tender
 6 Tender
 5 Moderately tender
 4 Acceptable
 3 Slightly tough
 2 Tough
 1 Extremely tough

Juiciness
 7 Extremely juicy
 6 Juicy
 5 Moderately juicy
 4 Acceptable
 3 Slightly dry
 2 Dry
 1 Extremely dry

Overall Acceptability
 7 Extremely desirable
 6 Desirable
 5 Moderately desirable
 4 Acceptable
 3 Slightly undesirable
 2 Undesirable
 1 Extremely undesirable

Degree of Doneness
 3 Well-done
 2 Medium-done
 1 Rare

Comments:

Form II.

5-944 1972

Instructions to Judges for Sensory Evaluation of Beef Top Round, Semimembranosus and Adductor Muscles

Scoring for Degree of Doneness

Evaluate the degree of doneness for the samples placed under the MacBeth Skylight. Please record those scores before proceeding to the other evaluations.

You may select 2 cubes of meat at random from each double boiler for sampling, one cube for counting chews and evaluating tenderness, and one for assessing flavor, juiciness, and overall acceptability.

Scoring for flavor and juiciness

Record a score for flavor and another for juiciness within a range of 7 to 1 that describes your impression of the sample. See the score card for descriptive terms for specific scores within the range of 7 to 1. Record the score describing your impression of flavor and juiciness at the beginning of the chewing process.

Scoring for tenderness

Count the number of times you chew the 1/2-in. (1.3-cm) cube of meat before swallowing. Chew until the cube is masticated completely, then swallow. Record the number of chews required to masticate the cube. Record a score from 7 to 1 that describes your impression of the tenderness of the cube. See the score card for descriptive terms for specific scores within the range of 7 to 1.

Use the number of chews to help you standardize your tenderness scores from day to day. Set up for yourself a range of the number of chews for each score from 7 to 1. For example, if you chew from 15 to 25 times, you might record a score of 7; if you chew 25 to 35 times, a score of 6; 35 to 45 times, a score of 5; continuing to reduce the score by a given number of increased chews. Each judge sets his own range of chews for a given score.

Overall Acceptability

Record a score that describes your impression of the general desirability of the sample. This is not a total score, i.e., it is not a score obtained by adding the scores for the other factors. Score overall acceptability within the range of 7 to 1, the same as for each of the other factors listed on the score card.

Comments

Comments about a sample and/or explaining your reason for giving a particular score are helpful.

Take your time to score each sample. Water is provided for rinsing your mouth between samples.

Table 6-Means and F-values for non-significant type of heat x end point temperature interactions

Measurement	Type of heat	End point temperature, °C			F-value
		60	70	80	
Initial weight, kg	Dry	1.06	1.03	1.16	0.92 ns
	Moist	1.14	1.20	1.14	
Volume of drippings, ml	Dry	8.50	10.67	4.17	1.70 ns
	Moist	194.83	241.00	157.50	
Lipid in drippings, % of volume	Dry	14.03	9.97	30.43	1.98 ns
	Moist	3.67	3.22	5.27	
Water-holding capacity ^a	Dry	0.8151	0.8068	0.7822	0.46 ns
	Moist	0.7712	0.7602	0.7594	
Shear value, kg/1.3-cm core	Dry	2.79	3.94	3.57	0.47 ns
	Moist	3.48	3.76	3.85	
Color-difference, Gardner Rd (reflectance)	Dry	19.67	19.53	21.24	0.13 ns
	Moist	19.98	20.27	21.57	
b* (yellowness)	Dry	10.97	10.90	9.61	3.16 ns
	Moist	10.29	10.40	10.77	
Sensory scores Juiciness ^b	Dry	5.5	5.9	4.5	0.19 ns
	Moist	4.8	5.0	4.2	
Tenderness ^b	Dry	5.9	5.8	5.3	3.47 ns
	Moist	5.2	5.0	5.6	
Overall Acceptability ^b	Dry	5.1	5.6	5.1	1.75 ns
	Moist	5.3	5.1	4.8	

^a1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^b7-(extremely desirable, juicy, tender); 1-(extremely undesirable, dry, tough)

Table 7-Means and F-values for oven temperature, °C, x end point temperature, °C, interaction

Measurement	Oven temp., °C	End point temperature, °C			F-value
		60	70	80	
Initial weight, kg	177	1.03	1.11	1.11	0.62 ns
	205	1.17	1.12	1.20	
Cooking time Total, min	177	101.83	115.50	130.17	0.68 ns
	205	97.00	99.00	117.17	
Min/kg	177	98.32	106.06	118.54	0.13 ns
	205	84.36	90.52	101.33	
Cooking losses, % Total	177	27.39	32.44	33.64	2.46 ns
	205	28.44	30.74	35.00	
Dripping	177	12.20	13.44	10.06	0.01 ns
	205	9.45	11.04	7.46	
Volatile	177	19.12	24.28	28.90	0.72 ns
	205	22.96	25.68	31.40	
Volume of drippings, ml	177	106.00	140.33	87.50	0.13 ns
	205	97.33	111.33	74.17	
Lipid in drippings, % of volume	177	7.65	6.87	25.02	1.66 ns
	205	10.05	6.32	10.68	
Total moisture, %	177	67.20	64.71	63.86	1.70 ns
	205	66.70	65.93	63.58	
Water-holding capacity ^a	177	0.7810	0.7780	0.7730	0.56 ns
	205	0.8052	0.7890	0.7686	

Table 7--(concluded)

Measurement	Oven temp., °C	End point temperature, °C			F-value
		60	70	80	
Shear value, kg/1.3-cm core	177	2.85	3.56	3.61	0.12 ns
	205	3.41	4.15	3.80	
Color-difference, Gardner Rd (reflectance)	177	20.79	21.15	21.30	2.79 ns
	205	18.67	18.65	21.52	
a+ (redness)	177	6.78	3.50	2.52	1.82 ns
	205	5.81	4.89	2.41	
b+ (yellowness)	177	10.71	10.67	9.62	1.60 ns
	205	10.55	10.63	10.77	
Sensory scores Flavor ^b	177	5.5	5.6	5.4	0.59 ns
	205	5.4	5.6	5.8	
Juiciness ^b	177	4.6	5.8	4.9	2.79 ns
	205	5.6	5.1	3.8	
Tenderness ^b	177	5.6	5.3	5.8	2.71 ns
	205	5.6	5.6	5.1	
Overall acceptability ^b	177	5.2	5.3	5.1	0.37 ns
	205	5.2	5.3	4.8	
Apparent degree of doneness ^c	177	2.2	2.2	2.2	1.94 ns
	205	1.9	2.2	2.6	

^a1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^b7-(extremely desirable, juicy, tender); 1-(extremely undesirable, dry, tough)

^c3-well-done; 2-medium-done; 1-rare

Table 8-Means and F-values for type of heat x end point temperature x oven temperature interaction

Measurement	Oven temp.	Type of heat	End point temperature, °C			F-value
			60	70	80	
Initial weight, kg	177	Dry	0.98	0.96	1.13	0.92 ns
		Moist	1.07	1.25	1.08	
	205	Dry	1.13	1.10	1.18	
		Moist	1.20	1.14	1.21	
Cooking time Total, min	177	Dry	96.33	108.33	143.67	1.94 ns
		Moist	107.33	122.67	116.67	
	205	Dry	96.00	105.67	124.33	
		Moist	98.00	92.33	110.00	
Min/kg	177	Dry	96.66	112.62	129.16	0.49 ns
		Moist	99.97	99.50	107.92	
	205	Dry	85.62	96.76	108.44	
		Moist	83.11	84.27	94.23	
Cooking losses, % Total	177	Dry	21.05	27.27	31.03	1.12 ns
		Moist	33.74	37.62	36.24	
	205	Dry	24.92	28.56	33.34	
		Moist	31.96	32.92	36.67	
Dripping	177	Dry	1.92	2.99	2.14	0.11 ns
		Moist	22.49	23.90	17.98	
	205	Dry	1.77	2.21	1.94	
		Moist	17.14	19.86	12.99	

Table 8-(continued)

Measurement	Oven temp.	Type of heat	End point temperature, °C			F-value
			60	70	80	
Volume of drippings, ml	177	Dry	6.67	9.67	4.67	0.13 ns
		Moist	205.33	271.00	170.33	
	205	Dry	10.33	11.67	3.67	
		Moist	184.33	211.00	144.67	
Lipid in drippings, % of volume	177	Dry	11.80	9.67	45.87	2.29 ns
		Moist	3.50	4.07	4.17	
	205	Dry	16.27	10.27	15.00	
		Moist	3.83	2.37	6.37	
Total moisture, %	177	Dry	69.71	67.34	64.52	0.81 ns
		Moist	64.70	62.09	63.21	
	205	Dry	68.80	67.32	64.50	
		Moist	64.60	65.55	62.66	
Water-holding capacity ^a	177	Dry	0.8016	0.8099	0.7929	0.00 ns
		Moist	0.7514	0.7461	0.7531	
	205	Dry	0.8196	0.8037	0.7716	
		Moist	0.7910	0.7743	0.7657	
Shear value, kg/1.3-cm core	177	Dry	2.2	3.2	3.0	0.13 ns
		Moist	3.5	3.9	4.3	
	205	Dry	3.4	4.6	4.2	
		Moist	3.5	3.6	3.4	
Color-difference, Gardner Rd (reflectance)	177	Dry	20.77	20.55	20.97	0.10 ns
		Moist	20.81	21.75	21.62	

Table 8-(continued)

Measurement	Oven temp.	Type of heat	End point temperature, °C			F-value
			60	70	80	
Color-difference, Gardner						
Rd (reflectance)	205	Dry	18.57	18.51	21.51	
		Moist	18.76	18.79	21.52	
a+ (redness)	177	Dry	11.19	5.10	2.81	1.65 ns
		Moist	2.37	1.90	2.23	
	205	Dry	10.76	10.81	10.77	
		Moist	3.44	3.51	2.07	
b+ (yellowness)	177	Dry	11.18	10.99	8.46	1.90 ns
		Moist	10.24	10.36	10.78	
	205	Dry	10.76	10.81	10.77	
		Moist	10.34	10.45	10.77	
Sensory scores						
Flavor ^b	177	Dry	5.3	5.5	6.1	0.21 ns
		Moist	5.7	5.6	4.8	
	205	Dry	4.8	5.1	5.8	
		Moist	6.0	6.1	5.8	
Juiciness ^b	177	Dry	4.6	6.0	5.0	0.28 ns
		Moist	4.7	5.6	4.8	
	205	Dry	6.4	5.8	4.0	
		Moist	4.9	4.5	3.7	
Tenderness ^b	177	Dry	5.8	5.7	5.5	0.19 ns
		Moist	5.4	4.9	6.1	
	205	Dry	6.1	6.0	5.1	
		Moist	5.1	5.2	5.1	

Table 8-(concluded)

Measurement	Oven temp.	Type of heat	End point temperature, °C			F-value
			60	70	80	
Overall Acceptability ^b	177	Dry	5.1	5.7	5.4	0.46 ns
		Moist	5.3	4.9	4.8	
	205	Dry	5.3	5.4	4.8	
		Moist	5.3	5.2	4.8	
Apparent degree of doneness ^c	177	Dry	1.8	1.8	2.4	0.15 ns
		Moist	2.6	2.7	2.1	
	205	Dry	1.3	1.7	2.6	
		Moist	2.5	2.7	2.7	

^a1.0 minus (expressible liquid index); the larger the value, the greater the amount of liquid expressed

^b7-(extremely desirable, juicy or tender); 1-(extremely undesirable, dry or tough)

^c3-well-done; 2-medium-done; 1-rare

Table 9-Rate of heat penetration in minutes to reach 10°C and to increase every 5°C from 10°C to 60°, 70°, or 80°C

	Temperature, °C													
	n-10	15	20	25	30	35	40	45	50	55	60	65	70	75 80
Oven temp. (T)														
177°C	67.4	3.7	3.2	3.0	3.2	3.3	3.4	4.2	3.9	4.3	4.8	4.7	5.6	6.0 8.0
205°C	59.4	4.9	3.5	4.0	3.6	3.2	3.3	3.1	3.3	3.1	3.9	4.1	3.8	4.7 4.2
Type of heat (H)														
Dry	58.4	4.3	3.6	3.9	3.6	3.6	3.8	4.1	4.2	4.4	5.3	5.5	6.2	7.7 8.5
Moist	68.4	4.3	3.2	3.6	3.2	2.9	2.8	3.3	3.1	2.9	3.4	3.2	3.2	3.0 3.7
End point temp. (P)														
60°C	63.3	4.2	3.8	3.0	3.3	3.4	3.2	3.2	4.0	3.5	4.6			
70°C	62.0	4.2	3.5	3.6	3.2	3.0	3.4	3.8	3.3	3.5	4.1	4.1	4.8	
80°C	64.9	4.5	2.8	3.9	3.6	3.4	3.3	4.0	3.5	4.1	4.5	4.7	4.6	---
T x H														
177, Dry	59.4	3.6	3.6	3.0	3.4	3.7	4.0	4.6	4.3	5.1	6.0	5.8	7.3	9.0 11.3
177, Moist	75.3	3.8	2.9	3.0	3.0	3.0	2.8	3.9	3.4	3.4	3.7	3.5	3.8	3.0 4.7
205, Dry	57.4	5.0	3.6	3.8	3.7	3.6	3.7	3.6	4.0	3.8	4.7	5.2	5.0	6.3 5.7
205, Moist	61.4	4.9	3.4	4.2	3.4	2.9	2.9	2.7	2.7	2.4	3.2	3.0	2.7	3.0 2.7
T x P														
177, 60	63.5	4.0	4.2	3.3	3.5	3.8	3.5	3.2	4.3	4.0	4.7			
177, 70	69.2	3.7	3.3	2.7	3.2	2.8	3.5	4.8	3.7	4.2	4.5	4.5	5.5	

Table 9--(continued)

	Temperature, °C													
	n-10	15	20	25	30	35	40	45	50	55	60	65	70	75 80
T x P														
177, 80	69.5	3.3	2.2	3.0	3.0	3.3	3.2	4.7	3.7	4.7	5.8	4.8	5.7	---
205, 60	63.2	4.3	3.3	2.7	3.2	3.0	3.0	3.2	3.7	3.0	4.5			
205, 70	54.8	4.8	3.7	4.5	3.3	3.2	3.3	2.8	3.0	2.8	3.7	3.7	4.2	
205, 80	60.3	5.7	3.5	4.8	4.2	3.5	3.5	3.3	3.3	3.5	3.7	4.5	3.5	---
H x P														
Dry, 60	55.8	4.3	4.5	3.2	3.7	3.8	3.7	3.7	4.2	4.0	5.2			
Dry, 70	57.3	4.0	3.3	3.5	3.3	3.0	4.0	3.7	4.2	4.2	4.8	5.0	6.0	
Dry, 80	62.2	4.5	2.8	3.5	3.7	4.0	3.8	4.8	4.2	5.2	6.0	6.0	6.3	---
Moist, 60	70.8	4.0	3.0	2.8	3.0	3.0	2.8	2.7	3.8	3.0	4.0			
Moist, 70	66.7	4.5	3.7	3.7	3.2	3.0	2.8	4.0	2.5	2.8	3.3	3.2	3.7	
Moist, 80	67.7	4.5	2.8	4.3	3.5	2.8	2.8	3.2	2.8	3.0	3.0	3.3	2.8	---
T x H x P														
177, Dry, 60	51.7	4.7	3.7	3.7	4.3	4.3	4.0	4.0	4.3	4.7	5.3			
177, Dry, 70	59.0	2.7	3.0	2.7	3.3	3.0	4.3	4.0	4.3	4.7	5.0	5.7	6.7	
177, Dry, 80	67.7	3.3	2.0	2.7	2.7	3.7	3.7	5.7	4.3	6.0	7.7	6.0	8.0	---
177, Moist, 60	75.3	3.3	2.7	3.0	2.7	3.3	3.0	2.3	4.3	3.3	4.0			

Table 9--(concluded)

T x H x P	Temperature, °C													
	n-10	15	20	25	30	35	40	45	50	55	60	65	70	75 80
177, Moist, 70	79.3	4.7	3.7	2.7	3.0	2.7	2.7	5.7	3.0	3.7	4.0	3.3	4.3	
177, Moist, 80	71.3	3.3	2.3	3.3	3.3	3.0	2.7	3.7	3.0	3.3	3.0	3.7	3.3	---
205, Dry, 60	60.0	4.0	3.3	2.7	3.0	3.3	3.3	3.3	4.0	3.3	5.0			
205, Dry, 70	55.7	5.3	3.7	4.3	3.3	3.0	3.7	3.3	4.0	3.7	4.7	4.3	5.3	
205, Dry, 80	56.7	5.7	3.7	4.3	4.7	4.3	4.0	4.0	4.0	4.3	4.3	6.0	4.7	---
205, Moist, 60	66.3	4.7	3.3	2.7	3.3	2.7	2.7	3.0	3.3	2.7	4.0			
205, Moist, 70	54.0	4.3	3.7	4.7	3.3	3.3	3.0	2.3	2.0	2.0	2.7	3.0	3.0	
205, Moist, 80	64.0	5.7	3.3	5.3	3.7	2.7	3.0	2.7	2.7	2.7	3.0	3.0	2.3	---

Table 10-Initial weight of roasts, kg

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Weight	An. and Roast number	Weight
177	60	1fR	1.11	1cL	1.01
		3fR	0.78	3bL	1.09
		5eR	1.06	5dR	1.12
		Mean	<u>0.98</u>		<u>1.07</u>
	70	1bL	1.08	1eR	1.22
		3dR	0.82	3aL	0.97
		5aL	0.99	5cL	1.57
		Mean	<u>0.96</u>		<u>1.57</u>
	80	1aL	0.91	1dR	1.04
		3cL	0.91	3eR	0.93
		5bL	1.58	5fR	1.29
		Mean	<u>1.13</u>		<u>1.08</u>
205	60	2fR	1.13	2aL	1.02
		4aL	0.92	4bL	0.94
		6aL	1.35	6bL	1.66
		Mean	<u>1.13</u>		<u>1.20</u>
	70	2dR	1.16	2eR	1.23
		4eR	0.95	4cL	0.70
		6cL	1.19	6dR	1.50
		Mean	<u>1.10</u>		<u>1.14</u>
	80	2bL	1.21	2cL	1.21
		4fR	0.75	4dR	0.82
		6fR	1.60	6eR	1.61
		Mean	<u>1.18</u>		<u>1.21</u>

Table 11-Total cooking time, min

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Time	An. and Roast number	Time
177	60	1fR	102.0	1cL	100.0
		3fR	71.5	3bL	105.0
		5eR	115.0	5dR	117.0
		Mean	<u>96.2</u>		<u>107.3</u>
	70	1bL	116.0	1eR	116.0
		3dR	97.5	3aL	109.0
		5aL	111.0	5cL	142.5
		Mean	<u>108.2</u>		<u>122.5</u>
	80	1aL	115.0	1dR	106.0
		3cL	130.0	3eR	108.0
		5bL	186.0	5fR	135.5
		Mean	<u>143.7</u>		<u>116.5</u>
205	60	2fR	89.0	2aL	91.0
		4aL	87.0	4bL	80.0
		6aL	112.0	6bL	123.0
		Mean	<u>96.0</u>		<u>98.0</u>
	70	2dR	107.0	2eR	97.0
		4eR	103.0	4cL	71.5
		6cL	106.5	6dR	108.0
		Mean	<u>105.5</u>		<u>92.2</u>
	80	2bL	122.0	2cL	115.0
		4fR	95.0	4dR	91.5
		6fR	155.5	6eR	122.5
		Mean	<u>124.2</u>		<u>109.7</u>

Table 12-Cooking time, min/kg

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Time	An. and Roast number	Time
177	60	1fR	91.8	1cL	99.2
		3fR	89.5	3bL	96.4
		5eR	108.7	5dR	104.3
		Mean	<u>96.7</u>		<u>100.0</u>
	70	1bL	107.2	1eR	94.8
		3dR	118.8	3aL	112.8
		5aL	111.9	5cL	90.8
		Mean	<u>112.6</u>		<u>99.5</u>
	80	1aL	126.6	1dR	102.4
		3cL	143.2	3eR	116.4
		5bL	117.6	5fR	105.5
		Mean	<u>129.1</u>		<u>107.9</u>
205	60	2fR	79.0	2aL	89.6
		4aL	95.0	4bL	85.5
		6aL	82.8	6bL	74.3
		Mean	<u>85.6</u>		<u>83.1</u>
	70	2dR	91.8	2eR	79.0
		4eR	108.6	4cL	102.0
		6cL	89.8	6dR	71.8
		Mean	<u>96.7</u>		<u>84.3</u>
	80	2bL	100.9	2cL	94.7
		4fR	127.2	4dR	112.0
		6fR	97.2	63R	76.0
		Mean	<u>108.4</u>		<u>94.2</u>

Table 13-Post-oven temperature rise

Oven temp., °C	End point temp., °C	Dry heat			Moist heat		
		An. and Roast number	Time	°C	An. and Roast number	Time	°C
177	60	1fR	18	.1	1cL	20	10
		3fR	--	0	3bL	19	11
		5eR	--	0	5dR	28	12
		Mean		<u>0.3</u>			<u>11</u>
	70	1bL	--	0	1eR	19	8
		3dR	--	0	3aL	15	6
		5aL	--	0	5cL	19.5	5
		Mean		<u>0</u>			<u>6.3</u>
	80	1aL	--	0	1dR	--	0
		3cL	--	0	3eR	13	3
		5bL	--	0	5fR	--	0
		Mean		<u>0</u>			<u>1</u>
205	60	2fR	--	0	2aL	--	0
		4aL	16	1	4bL	23	6
		6aL	--	0	6bL	26	8
		Mean		<u>0.3</u>			<u>4.7</u>
	70	2dR	--	0	2eR	18	8
		4eR	--	0	4cL	8.5	7
		6cL	--	0	6dR	--	0
		Mean		<u>0</u>			<u>5</u>
	80	2bL	--	0	2cL	--	0
		4fR	--	0	4dR	8.5	2
		6fR	--	0	6eR	--	0
		Mean		<u>0</u>			<u>0.7</u>

Table 14-Percentage total cooking losses

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Loss	An. and Roast number	Loss
177	60	1fR	22.4	1cL	32.9
		3fR	17.6	3bL	34.1
		5eR	23.2	5dR	34.2
		Mean	<u>21.1</u>		<u>33.7</u>
	70	1bL	25.2	1eR	37.5
		3dR	26.6	3aL	34.1
		5aL	34.0	5cL	37.8
		Mean	<u>28.6</u>		<u>36.5</u>
	80	1aL	27.4	1dR	34.6
		3cL	30.0	3eR	38.4
		5bL	35.7	5fR	35.8
		Mean	<u>31.0</u>		<u>36.3</u>
205	60	2fR	25.9	2aL	32.6
		4aL	23.7	4bL	30.3
		6aL	25.1	6bL	33.0
		Mean	<u>24.9</u>		<u>32.0</u>
	70	2dR	29.0	2eR	34.8
		4eR	27.8	4cL	31.0
		6cL	28.8	6dR	33.0
		Mean	<u>28.5</u>		<u>32.9</u>
	80	2bL	32.2	2cL	35.5
		4fR	30.9	4dR	36.7
		6fR	36.8	6eR	37.8
		Mean	<u>33.3</u>		<u>36.7</u>

Table 15-Percentage dripping cooking losses

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Loss	An. and Roast number	Loss
177	60	1fR	2.34	1cL	15.97
		3fR	1.54	3bL	25.16
		5eR	1.89	5dR	26.33
		Mean	<u>1.92</u>		<u>22.49</u>
	70	1bL	3.69	1eR	18.39
		3dR	3.16	3aL	25.87
		5aL	2.11	5cL	27.43
		Mean	<u>2.92</u>		<u>23.90</u>
	80	1aL	1.65	1dR	12.94
		3cL	1.98	3eR	19.50
		5bL	2.78	5fR	21.49
		Mean	<u>2.14</u>		<u>17.98</u>
205	60	2fR	1.95	2aL	15.90
		4aL	1.63	4bL	16.98
		6aL	2.29	6bL	18.53
		Mean	<u>1.96</u>		<u>17.14</u>
	70	2dR	2.57	2eR	20.45
		4eR	2.21	4cL	15.61
		6cL	1.85	6dR	23.38
		Mean	<u>2.21</u>		<u>19.81</u>
	80	2bL	1.73	2cL	9.39
		4fR	1.53	4dR	-----
		6fR	2.56	6eR	18.97
		Mean	<u>1.94</u>		<u>14.18</u>

Table 16-Percentage volatile cooking losses

Oven temp., °C	End point temp., °C	Dry heat	
		An. and Roast number	Loss
177	60	1fR	20.07
		3fR	16.04
		5eR	21.26
		Mean	<u>19.12</u>
	70	1bL	21.53
		3dR	23.38
		5aL	27.92
		Mean	<u>24.28</u>
	80	1aL	25.77
		3cL	27.97
		5bL	32.95
		Mean	<u>32.23</u>
205	60	2fR	23.97
		4aL	22.05
		6aL	22.85
		Mean	<u>28.90</u>
	70	2dR	24.43
		4eR	25.63
		6cL	26.98
		Mean	<u>25.68</u>
	80	2bL	30.52
		4fR	29.38
		6fR	34.29
		Mean	<u>31.40</u>

Table 17-Percentage total moisture

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Per- centage	An. and Roast number	Per- centage
177	60	1fR	69.68	1cL	66.70
		3fR	70.32	3bL	61.75
		5eR	69.12	5dR	65.66
		Mean	<u>69.71</u>		<u>64.73</u>
	70	1bL	66.38	1eR	60.75
		3dR	66.90	3aL	62.17
		5aL	68.74	5cL	63.35
		Mean	<u>67.34</u>		<u>62.09</u>
	80	1aL	63.62	1dR	63.15
		3cL	66.20	3eR	61.69
		5bL	63.75	5fR	64.78
		Mean	<u>64.52</u>		<u>63.21</u>
205	60	2fR	69.38	2aL	62.60
		4aL	68.90	4bL	66.15
		6aL	68.12	6bL	65.04
		Mean	<u>68.80</u>		<u>64.60</u>
	70	2dR	66.95	2eR	62.40
		4eR	66.06	4cL	65.32
		6cL	68.95	6dR	65.93
		Mean	<u>67.32</u>		<u>64.55</u>
	80	2bL	62.28	2cL	60.92
		4fR	66.16	4dR	63.45
		6fR	65.05	6eR	63.60
		Mean	<u>64.50</u>		<u>62.66</u>

Table 18-Gardner color-difference Rd (reflectance) values

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Rd value	An. and Roast number	Rd value
177	60	1fR	21.80	1cL	21.12
		3fR	21.20	3bL	21.65
		5eR	19.30	5dR	19.65
		Mean	<u>20.76</u>		<u>20.81</u>
	70	1bL	20.60	1eR	24.44
		3dR	22.33	3aL	21.94
		5aL	18.72	5cL	18.85
		Mean	<u>20.55</u>		<u>21.74</u>
	80	1aL	21.42	1dR	21.40
		3cL	20.81	3eR	22.31
		5bL	20.69	5fR	21.16
		Mean	<u>20.97</u>		<u>21.62</u>
205	60	2fR	15.95	2aL	19.15
		4aL	18.12	4bL	17.05
		6aL	21.65	6bL	20.08
		Mean	<u>18.57</u>		<u>18.76</u>
	70	2dR	16.00	2eR	14.75
		4eR	18.70	4cL	19.03
		6cL	20.82	6dR	19.03
		Mean	<u>18.51</u>		<u>18.79</u>
	80	2bL	21.56	2cL	22.14
		4fR	19.56	4dR	21.28
		6fR	23.42	6eR	21.15
		Mean	<u>21.51</u>		<u>21.52</u>

Table 19-Gardner color-difference a+ (redness) values

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	a+ value	An. and Roast number	a+ value
177	60	1fR	6.92	1cL	2.15
		3fR	15.60	3bL	2.40
		5eR	11.05	5dR	2.55
		Mean	<u>11.19</u>		<u>2.37</u>
	70	1bL	2.05	1eR	1.06
		3dR	7.36	3aL	2.05
		5aL	5.88	5cL	2.58
		Mean	<u>5.10</u>		<u>1.90</u>
	80	1aL	2.50	1dR	1.95
		3cL	3.36	3eR	2.46
		5bL	2.58	5fR	2.30
		Mean	<u>2.81</u>		<u>2.24</u>
205	60	2fR	9.30	2aL	2.35
		4aL	9.91	4bL	4.88
		6aL	5.35	6bL	3.09
		Mean	<u>8.19</u>		<u>3.44</u>
	70	2dR	6.02	2eR	3.92
		4eR	5.65	4cL	3.12
		6cL	7.14	6dR	3.49
		Mean	<u>6.27</u>		<u>3.31</u>
	80	2bL	2.34	2cL	1.75
		4fR	3.58	4dR	2.12
		6fR	2.35	6eR	2.35
		Mean	<u>2.76</u>		<u>2.07</u>

Table 20-Gardner color-difference b+ (yellowness) values

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	b+ value	An. and Roast number	b+ value
177	60	1fR	10.52	1cL	10.72
		3fR	12.22	3bL	10.31
		5eR	10.80	5dR	9.70
		Mean	<u>11.18</u>		<u>10.24</u>
	70	1bL	10.88	1eR	10.70
		3dR	11.55	3aL	10.48
		5aL	10.55	5cL	9.89
		Mean	<u>10.99</u>		<u>10.36</u>
	80	1aL	4.78	1dR	10.42
		3cL	10.38	3eR	11.28
		5bL	10.22	5fR	10.65
		Mean	<u>8.46</u>		<u>10.78</u>
205	60	2fR	10.35	2aL	10.18
		4aL	11.56	4bL	10.35
		6aL	10.38	6bL	10.50
		Mean	<u>10.76</u>		<u>10.34</u>
	70	2dR	10.50	2eR	10.02
		4aL	11.56	4cL	10.62
		6cL	11.25	6dR	10.70
		Mean	<u>11.10</u>		<u>10.44</u>
	80	2bL	10.28	2cL	10.70
		4fR	10.80	4dR	11.15
		6fR	11.22	6eR	10.45
		Mean	<u>10.77</u>		<u>10.77</u>

Table 21-Volume of drippings, ml

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Volume	An. and Roast number	Volume
177	60	1fR	10	1cL	117
		3fR	3	3bL	238.5
		5eR	7	5dR	260
		Mean	<u>6.7</u>		<u>205.2</u>
	70	1bL	13.5	1eR	202
		3dR	8.5	3aL	220
		5aL	6	5cL	391
		Mean	<u>9.3</u>		<u>271</u>
	80	1aL	4.5	1dR	119
		3cL	3	3eR	151
		5bL	5.5	5fR	241
		Mean	<u>4.3</u>		<u>170.3</u>
205	60	2fR	6.5	2aL	152
		4aL	6	4bL	135
		6aL	18	6bL	266
		Mean	<u>10.2</u>		<u>185</u>
	70	2dR	13	2eR	234
		4eR	9	4cL	95
		6cL	12.5	6dR	304
		Mean	<u>11.5</u>		<u>211</u>
	80	2bL	5	2cL	107
		4fR	4	4dR	67.5
		6fR	2	6eR	259
		Mean	<u>3.7</u>		<u>144.5</u>

Table 22-Lipid in drippings, percentage of volume

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Per- centage	An. and Roast number	Per- centage
177	60	1fR	20.0	1cL	2.6
		3fR	8.3	3bL	2.9
		5eR	7.1	5dR	5.0
		Mean	<u>11.8</u>		<u>3.5</u>
	70	1bL	14.8	1eR	3.5
		3dR	5.9	3aL	5.0
		5aL	8.3	5cL	3.7
		Mean	<u>9.7</u>		<u>4.1</u>
	80	1aL	30.00	1dR	4.2
		3cL	16.7	3eR	4.6
		5bL	90.9	5fR	3.7
		Mean	<u>45.9</u>		<u>4.2</u>
205	60	2fR	15.4	2aL	4.6
		4aL	16.7	4bL	3.7
		6aL	16.7	6bL	3.2
		Mean	<u>16.3</u>		<u>3.8</u>
	70	2dR	7.7	2eR	2.1
		4eR	11.1	4cL	2.1
		6cL	12.0	6dR	2.9
		Mean	<u>10.3</u>		<u>2.4</u>
	80	2bL	20.0	2cL	11.2
		4fR	12.5	4dR	4.4
		6fR	12.5	6eR	3.5
		Mean	<u>15.0</u>		<u>6.7</u>

Table 23-Water-holding capacity

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	WHC	An. and Roast number	WHC
177	60	1fR	0.8346	1cL	0.6675
		3fR	0.7973	3bL	0.7844
		5eR	0.7998	5dR	0.8023
		Mean	<u>0.8106</u>		<u>0.7514</u>
	70	1bL	0.8011	1eR	0.7529
		3dR	0.8333	3aL	0.7479
		5aL	0.7953	5cL	0.7374
		Mean	<u>0.8099</u>		<u>0.7461</u>
	80	1aL	0.8306	1dR	0.7607
		3cL	0.8149	3eR	0.7422
		5bL	0.7331	5fR	0.7564
		Mean	<u>0.7929</u>		<u>0.7531</u>
205	60	2fR	0.8222	2aL	0.7797
		4aL	0.8136	4bL	0.7949
		6aL	0.8231	6bL	0.7983
		Mean	<u>0.8196</u>		<u>0.7910</u>
	70	2dR	0.8312	2eR	0.7604
		4eR	0.7879	4cL	0.7588
		6cL	0.7920	6dR	0.8037
		Mean	<u>0.8037</u>		<u>0.7743</u>
	80	2bL	0.7587	2cL	0.7685
		4fR	0.7959	4dR	0.7363
		6fR	0.7602	6eR	0.7923
		Mean	<u>0.7716</u>		<u>0.7657</u>

Table 24-Warner-Bratzler shear, kg/1.3-cm core

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Shear value	An. and Roast number	Shear value
177	60	1fR	1.7	1cL	2.5
		3fR	2.2	3bL	5.1
		5eR	2.8	5dR	2.8
		Mean	<u>2.2</u>		<u>3.5</u>
	70	1bL	3.2	1eR	5.2
		3dR	3.4	3aL	3.5
		5aL	3.0	5cL	3.0
		Mean	<u>3.2</u>		<u>3.9</u>
	80	1aL	3.0	1dR	2.8
		3cL	2.8	3eR	5.7
		5bL	3.0	5fR	4.3
		Mean	<u>2.9</u>		<u>4.3</u>
205	60	2fR	3.1	2aL	1.3
		4aL	5.0	4bL	7.0
		6aL	2.0	6bL	2.1
		Mean	<u>3.4</u>		<u>3.5</u>
	70	2dR	3.9	2eR	5.1
		4eR	6.2	4cL	4.1
		6cL	3.9	6dR	1.8
		Mean	<u>4.7</u>		<u>3.7</u>
	80	2bL	3.7	2cL	3.3
		4fR	6.0	4dR	4.0
		6fR	2.8	6eR	3.0
		Mean	<u>4.2</u>		<u>3.4</u>

Table 25-Flavor scores; range, 7.0-extremely desirable to 1.0-extremely undesirable

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Score	An. and Roast number	Score
177	60	1fR	5.0	1cL	5.3
		3fR	5.8	3bL	6.0
		5eR	5.0	5dR	5.7
		Mean	<u>5.3</u>		<u>5.7</u>
	70	1bL	5.3	1eR	5.5
		3dR	5.2	3aL	6.0
		5aL	6.0	5cL	5.3
		Mean	<u>5.5</u>		<u>5.6</u>
	80	1aL	5.7	1dR	5.3
		3cL	5.8	3eR	3.3
		5bL	6.7	5fR	5.7
		Mean	<u>6.1</u>		<u>4.8</u>
205	60	2fR	4.2	2aL	5.5
		4aL	5.0	4bL	6.4
		6aL	5.3	6bL	6.2
		Mean	<u>4.8</u>		<u>6.0</u>
	70	2dR	5.0	2eR	5.8
		4eR	4.7	4cL	6.2
		6cL	5.5	6dR	6.2
		Mean	<u>5.1</u>		<u>6.1</u>
	80	2bL	6.0	2cL	5.7
		4fR	5.7	4dR	6.0
		6fR	5.7	6eR	5.8
		Mean	<u>5.8</u>		<u>5.8</u>

Table 26--Juiciness scores; range, 7.0-extremely juicy to 1.0-extremely dry

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Score	An. and Roast number	Score
177	60	1fR	4.7	1cL	4.5
		3fR	3.2	3bL	5.0
		5eR	6.3	5dR	4.7
		Mean	<u>4.7</u>		<u>4.7</u>
	70	1bL	5.9	1eR	4.2
		3dR	5.8	3aL	4.0
		5aL	6.3	5cL	3.7
		Mean	<u>6.0</u>		<u>4.0</u>
	80	1aL	5.8	1dR	4.3
		3cL	5.2	3eR	6.5
		5bL	4.0	5fR	3.7
		Mean	<u>5.0</u>		<u>4.8</u>
205	60	2fR	6.7	2aL	5.2
		4aL	6.2	4bL	4.4
		6aL	6.2	6bL	5.2
		Mean	<u>6.4</u>		<u>4.9</u>
	70	2dR	5.8	2eR	3.8
		4eR	5.7	4cL	4.6
		6cL	5.8	6dR	5.0
		Mean	<u>5.8</u>		<u>4.5</u>
	80	2bL	4.2	2cL	4.0
		4fR	4.2	4dR	3.3
		6fR	3.7	6eR	3.7
		Mean	<u>4.0</u>		<u>3.7</u>

Table 27-Tenderness scores; range, 7.0-extremely tender to 1.0-extremely tough

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Score	An. and Roast number	Score
177	60	1fR	6.3	1cL	5.8
		3fR	4.8	3bL	5.5
		5eR	6.2	5dR	4.8
		Mean	<u>5.8</u>		<u>5.4</u>
	70	1bL	5.5	1eR	4.7
		3dR	5.2	3aL	5.3
		5aL	6.3	5cL	4.7
		Mean	<u>5.7</u>		<u>4.9</u>
	80	1aL	5.2	1dR	5.5
		3cL	6.0	3eR	6.7
		5bL	5.3	5fR	6.0
		Mean	<u>5.5</u>		<u>6.1</u>
205	60	2fR	6.7	2aL	5.0
		4aL	5.4	4bL	4.4
		6aL	6.2	6bL	5.0
		Mean	<u>6.1</u>		<u>4.8</u>
	70	2dR	6.0	2eR	4.8
		4eR	5.8	4cL	5.0
		6cL	6.3	6dR	5.8
		Mean	<u>6.0</u>		<u>5.2</u>
	80	2bL	5.0	2cL	5.3
		4fR	5.5	4dR	4.8
		6fR	4.7	6eR	5.2
		Mean	<u>5.1</u>		<u>5.1</u>

Table 28-Overall acceptability scores; range, 7.0-extremely desirable to 1.0-extremely undesirable

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Score	An. and Roast number	Score
177	60	1fR	5.3	1cL	5.2
		3fR	4.8	3bL	5.5
		5eR	5.2	5dR	5.2
		Mean	<u>5.1</u>		<u>5.3</u>
	70	1bL	5.7	1eR	4.5
		3dR	5.2	3aL	5.5
		5aL	6.3	5cL	4.7
		Mean	<u>5.7</u>		<u>4.9</u>
	80	1aL	5.3	1dR	5.3
		3cL	5.5	3eR	3.8
		5bL	5.3	5fR	5.3
		Mean	<u>5.4</u>		<u>4.8</u>
205	60	2fR	4.5	2aL	5.5
		4aL	5.0	4bL	5.0
		6aL	6.0	6bL	5.5
		Mean	<u>5.2</u>		<u>5.3</u>
	70	2dR	5.3	2eR	5.0
		4eR	5.0	4cL	5.0
		6cL	6.0	6dR	5.7
		Mean	<u>5.4</u>		<u>5.2</u>
	80	2bL	5.2	2cL	5.0
		4fR	4.8	4dR	4.7
		6fR	4.5	6eR	4.8
		Mean	<u>4.8</u>		<u>4.8</u>

Table 29-Apparent degree of doneness (1 = rare, 2 = medium-done, 3 = well-done)

Oven temp., °C	End point temp., °C	Dry heat		Moist heat	
		An. and Roast number	Score	An. and Roast number	Score
177	60	1fR	1.2	1cL	2.7
		3fR	2.8	3bL	2.7
		5eR	1.5	5dR	2.5
		Mean	<u>1.8</u>		<u>2.6</u>
	70	1bL	1.6	1eR	2.5
		3dR	1.7	3aL	2.5
		5aL	2.2	5cL	3.0
		Mean	<u>1.8</u>		<u>2.7</u>
	80	1aL	2.3	1dR	2.5
		3cL	2.0	3eR	1.0
		5bL	3.0	5fR	2.7
		Mean	<u>2.4</u>		<u>2.1</u>
205	60	2fR	1.0	2aL	2.3
		4aL	1.4	4bL	2.6
		6aL	1.5	6bL	2.7
		Mean	<u>1.3</u>		<u>2.5</u>
	70	2dR	1.5	2eR	2.8
		4eR	1.9	4cL	2.6
		6cL	1.8	6dR	2.7
		Mean	<u>1.7</u>		<u>2.7</u>
	80	2bL	2.5	2cL	2.7
		4fR	2.4	4dR	2.7
		6fR	2.8	6eR	2.7
		Mean	<u>2.6</u>		<u>2.7</u>

EFFECTS OF END POINT AND OVEN TEMPERATURES ON BEEF ROASTS
COOKED IN OVEN FILM AND OPEN PANS

by

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Oven film cooking bags are offered to the homemaker as a new method of meat cookery. Film bags are marketed under several brand names, and one manufacturer suggests that lower cost, less tender cuts of meat ideally are suited to cooking in film. This is in agreement with the usual recommendation that moist heat (braising or pot roasting) be used to cook less tender cuts to soften collagenous connective tissue. Manufacturers sometimes imply in advertising that their product will produce a juicier, more flavorful roast in a shorter time than is otherwise possible.

A split plot design was followed to cook 36 top round roasts by dry and moist heat (open pans and oven film) at 177° or 205°C to 60°, 70°, or 80°C. Total and dripping losses and volume of drippings were less ($P < 0.001$) for roasts cooked by dry heat than for those cooked by moist heat. Total moisture was greater ($P < 0.001$) and roasts were tenderer ($P < 0.05$) when cooked by dry heat. Cooking time and Gardner Rd values increased ($P < 0.05$) between 60° and 80°C and between 70° and 80°C. Gardner at values decreased ($P < 0.05$) with increasing end point temperature. Total and volatile losses increased ($P < 0.05$) with increasing end point; dripping losses increased slightly between 60° and 70°C, then decreased ($P < 0.05$) between 70° and 80°C. No sensory characteristic was affected by end point or oven temperature; no objective measurement was affected by oven temperature. Interactions between type of heat and end point temperature indicate that differences ($P < 0.01$) in total moisture between dry and moist heat were attributable to differences at 60° and 70°C. Differences among end point temperatures for apparent degree of doneness scores showed the panel preferred flavor of meat that appeared well-done.